Georgia Tech Center for Serve-Learn-Sustain

SLS Final Deliverables: Energy Systems for Sustainable Communities Fellows Program

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Energy performance contracting (EPC) at the Georgia Tech campus: An economic decision analysis model and a case study

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Overview of Energy Performance Contracting (EPC): Recently, many Energy Services Companies (ESCOs) have executed Energy Conservation Measures (ECMs) in the form of Guaranteed Energy Savings Performance Contracts (GESPCs). GESPCs guarantee that energy savings will meet or exceed the cost of payments, including financing costs, M&V, maintenance, etc. Georgia Tech currently is in the contract with Johnson Controls to enhance energy and water efficiency in the Holland Plant, 10^{th} Street Plant, and several other buildings on the campus. Johnson Controls assures that the Georgia Institute of Technology (GT) shall achieve guaranteed project benefits in accordance with the terms of this Agreement.

Our research objective is to develop a financial evaluation model to assess the risk of investment in energy performance contracting. Our research hypothesis is that energy performance contracting (EPC) has tremendous potentials in bridging the gap in energy efficiency through providing the private sectors' expertise, innovation and financial capital to overcome several barriers in achieving the greatest level of energy efficiency. It is believed that EPC can be an effective form of public-private partnership (P3) to enhance the state of energy efficiency in public buildings. Enhancing the state of energy efficiency in government buildings and improving the quality of indoor environment contribute substantially to the sustainable and just development.

Overview of Barriers in Energy Efficiency: It is recognized that economic barriers, such as cost-effectiveness and fiscal barriers, and non-economic barriers, such as regulatory, statutory, behavioral, and cultural factors, hinder the implementation of building energy technologies (Figure 1). Excellent discussions of barriers to building energy investments and market-based or policy instruments to facilitate technology adoption have been offered by the Committee on Climate Change Science and Technology Integration (2009), the National Academy of Engineering (2009), McKinsey (2009), and Stavins (2003).

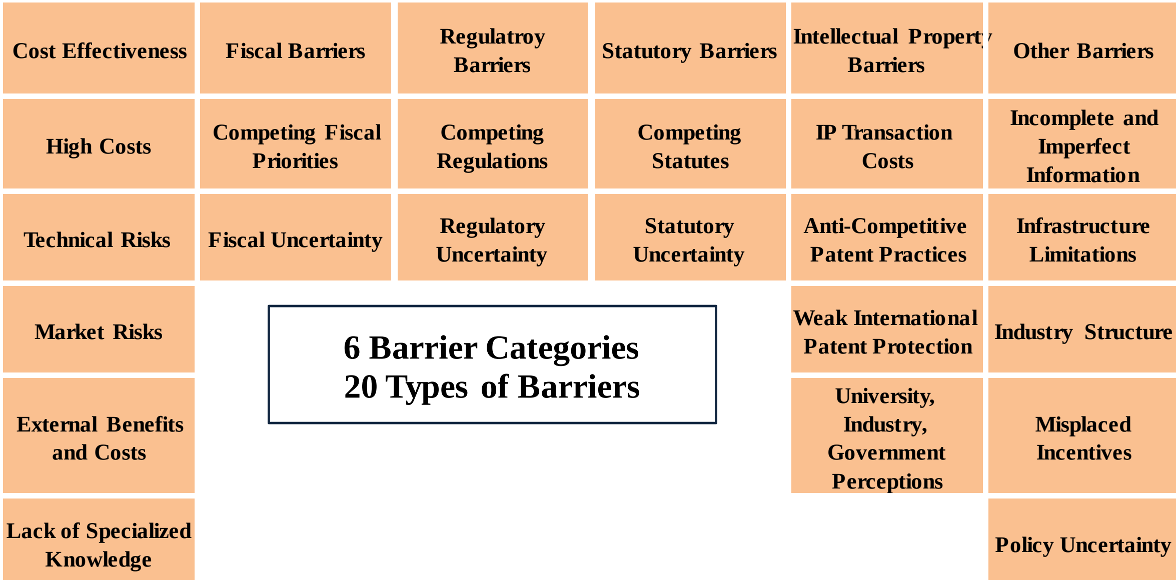

Figure 1. Barriers Hindering Investments in Building Energy Efficiency

If utilized effectively, EPC can be an efficient instrument in advancing the state of private investments in buildings for improving the indoor environmental quality and energy efficiency.

Definition of energy savings: Energy savings are defined as the amount of energy saved or avoided through the implementation of energy improvements. The International Performance Measurement and Verification Protocol (IPMVP 2010) will be adopted to establish the definition of energy savings in this project. This protocol is widely used to determine energy savings in energy improvement projects (Roosa 2010). Figure 2 schematically shows the longitudinal energy savings following the implementation of an energy improvement. These energy savings represent the difference between the post-implementation measured energy and the corresponding adjusted baseline energy. The two profiles for the pre-implementation baseline energy and the post-implementation measured energy for a building are retrieved from monthly utility bills. Adjusted baseline energy represents how much energy would be consumed in the building if there was no improvement. The profile for the adjusted baseline energy does not exist. Therefore, a proper method should be devised to describe the adjusted baseline energy.

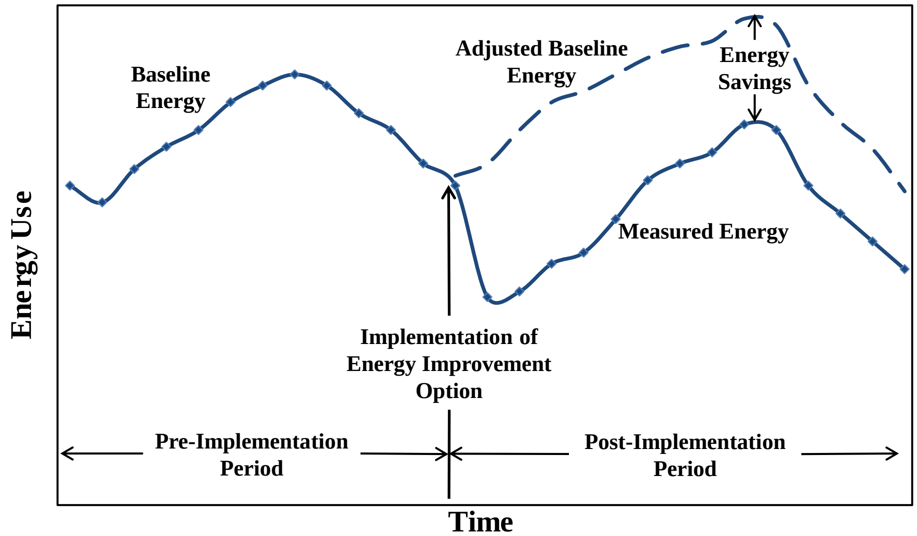

Figure 2. Energy Savings Following the Implementation of Improvement Option (Adopted from IPMVP 2010)

One of the main challenges of EPC is the presence of considerable uncertainty about the extent of potential energy savings.

Uncertainty about Energy Saving in EPC Contracts:

Risk about Future Retail Price of Energy: Since 1982, Energy Information Administration (EIA) has published Annual Energy Outlook (AEO), which provides projection of US energy supply, demand, and prices based on EIA's National Energy Modeling System (NEMS) (Figure 3). Besides NEMS, there are several Energy Market simulation models, e.g., IPM, HAIKU, NE-MARKAL, and SEDS (Blair et al. 2009), for describing energy price trends.

The main problem is that forecasted energy prices are based on business-as-usual assumptions and do not reflect the likely impact of future regulations, radical technology advances, and extreme events on supply-demand balance (Fischer et al. 2008). Therefore, energy price forecasts are highly uncertain (EIA 2011) as the historical "actual to forecast" ratios show. Uncertainty about future prices of energy delays investment in energy improvement projects and makes investment valuation problematic for energy performance contracting.

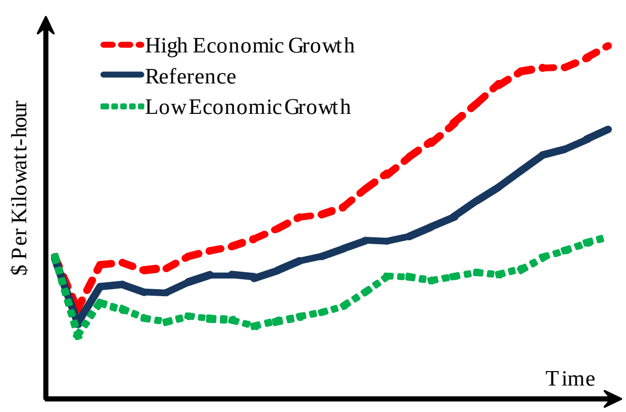

Figure 3. Future Scenarios for Energy Price

Considering substantial uncertainty about future energy savings, there is a need for novel methods for economic decision analysis of EPC projects as current investment valuation methods are limited.

Limitations of existing investment valuation methods for EPC contracts: Several methods have traditionally been used to evaluate investments in building energy improvements as summarized in Table 1. The surveys of using these methods in the green building industry can be found in Muldavin (2010) and Prindle and de Fontaine (2009). Of all these measures, NPV is the de-facto standard, accepted method in the literature of sustainability valuation (ASTM E917–05 2010; Montoya 2010; Vanek and Albright 2008; Kibert 2008; BRE and Sweett 2005).

Table 1. Conventional Investment Valuation Methods

Method	Description	Limitations
Payback Period (PP)	Time that it takes to repay total initial investment	• Ignoring time value of money and investment risks • Stressing on capital recovery not profitability
Return on Investment (ROI)	Number of times the net benefits recover the original investment	• Ignoring the time value of money or investment risks
Net Present Value (NPV)	Sum of present values of the entire incoming and outgoing cash flows	• Assuming all decisions are made at once and are completely irrevocable • Not capturing the value of delayed investments

Limitations of NPV in Capturing Investment Timing under Uncertainty in EPC Contracts: NPV analysis assumes that an energy investment decision is made at one time and is irrevocable. These assumptions are not consistent with real-world decision-making for energy investments in buildings. Energy management decisions are made over time as building systems degrade and building energy market conditions evolve. Moreover, there are a large number of emerging technologies that can be considered for energy improvements either through renewable energy production or efficiency measures. Many technologies are still in their early development stages. It is expected that they will become less expensive and more efficient in the future due to the economies of scale. Also, one cannot be confident about actual energy-saving potential of these technologies due to uncertainty about technical performance and deterioration. Therefore, it might be reasonable to delay investing in these technologies but maintain the capacity to implement them in the future when technical and financial conditions become favorable. For instance, installing Photovoltaic (PV) panels may not be an economically attractive technology today but it could be a financially wise choice to prepare a building for easy installation of PV panels in the future. Due to inherent limitations, NPV analysis leads to the elimination of promising technologies from the investment list although a more financially justified strategy can keep some of the improvement options alive and (possibly) adopt them in the future once the technologies become available at lower costs, energy becomes more expensive, or stricter regulations are put in place making improvements a necessity. The key element missing from the NPV approach is investment timing. Thus, there is a need for a novel valuation method to quantify uncertainty about energy savings in the EPC and takes the quantified uncertainty into account for creating an accurate economic analysis model for evaluating EPC projects under uncertainty.

Uncertainty Quantification of Energy Improvement Projects: Uncertainty about energy savings plays a critical role in building energy improvements and more specifically delaying these improvements (NAS 2009; Brown 2001; Hassett and Metcalf 1993). There is a need to depart from current deterministic evaluation of energy savings. Uncertainty about building energy savings should be rigorously quantified and properly integrated into economic valuation of energy performance contracting. Uncertainty quantification is enabled by identifying and quantifying sources of uncertainties, such as system parameters and usage scenarios, and propagating them through proper energy simulation tools. Long-term uncertainties about energy savings following building energy improvements are due to several factors, including changes in physical properties of building systems (Chorier et al. 2010; Loy et al. 2004; Kirkham et al. 2004), building maintenance policies (Blom et al. 2010), building occupancy and operations (de Wilde et al. 2011), and weather patterns (Wang et al. 2010; Murphy et al. 2009). For instance, current photovoltaic (PV) technologies lose efficiency over time at a rate of between 0.75% and 1% per year (Adelstein and Sekulic 2005).

Use of an alternative investment valuation method to justify EPC projects: Real options analysis provides a proper economic and investment valuation methodology to cope with investment timing under uncertainty in energy performance contracting. The term real options refers to the assessment of real (non-financial) investments with strategic management flexibility features like delayed improvement (Dixit and Pindyck 1994). This field has gone through a massive transition from a topic of modest academic interest in the 1990s to the current considerable, active academic and industry attention (Ford and Garvin 2010; Borison 2005). Several real options analysis models are found in the literature to evaluate energy improvement projects in buildings (Reisi et al. 2016; Kashani et al. 2015; Ashuri et al. 2013; Ashuri et al. 2011; Kolahdoozan and Ashuri 2010). Figure 4 illustrates the difference between the NPV and real options valuation approach.

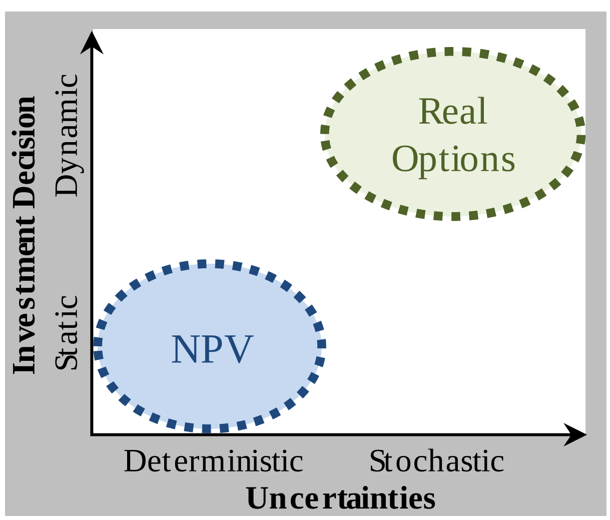

Figure 4. NPV vs. Real Options

Our goal in this research is to develop a new real options model to evaluate EPC projects under various sources of uncertainties. A GT EPC project is used as a case study in this research.

Overview of the GT case study:

Georgia Tech currently is in the contract with Johnson Controls to enhance energy and water efficiency in the Holland Plant, 10th Street Plant, and several other buildings on the campus. An overview of the EPC process is presented in Figure 5.

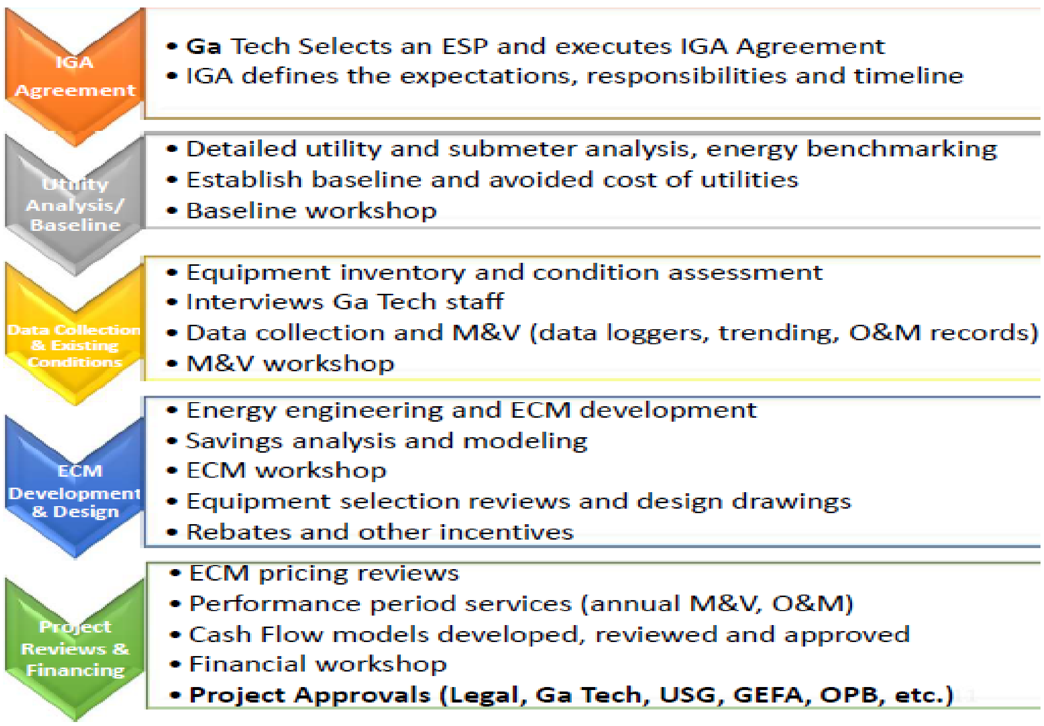

Figure 5. An overview of the process for developing an EPC project at GT

Since Georgia Tech is a district energy system, it is evident that the primary focus of the subject ECM should be on a central plant in charge of producing chilled water and/or steam. The steam or water is distributed through underground piping networks to buildings or zones for space heating, domestic water heating, and air conditioning. This is considered cost efficient in comparison to a collection of individual heating, ventilation and air conditioning systems. Currently, Georgia Tech has two main central plants. A majority of buildings on GT main campus – including classroom buildings, office buildings, research buildings, residential buildings and athletic facilities – are connected to either Holland plant or Tenth street plant. Thus, it is important to seamlessly run each plant in an energy efficient way since it consumes the largest amount of energy on campus throughout year. Maximizing its efficiency, however, is not a straightforward task. The plant is a complicated engineered system, composed of various machines and instrumentation that require precise care and high maintenance, often labor intensive. Further, finding optimal operation parameters is extremely challenging, as they are dependent on conditions such as weather and system load profiles that change all the time. In many central plants, primary-secondary chilled water systems have been prevailing, as they are relatively simple to implement and fault tolerant in response to control errors although they come at the price of built-in efficiency. One of the major task of the EPC is to improve the efficiency of the two central plants by retrofitting several chillers and the chilled water distribution systems and upgrading the chiller dispatching strategies and control algorithms. The construction successfully ended on June 30, 2017 and since then the fully automated control system has achieved about 30% of improvement in terms of the plant efficiency metric (kW/Ton).

3D Printing with Recycled Plastics: Maker Spaces for Sustainable Environments and Communities

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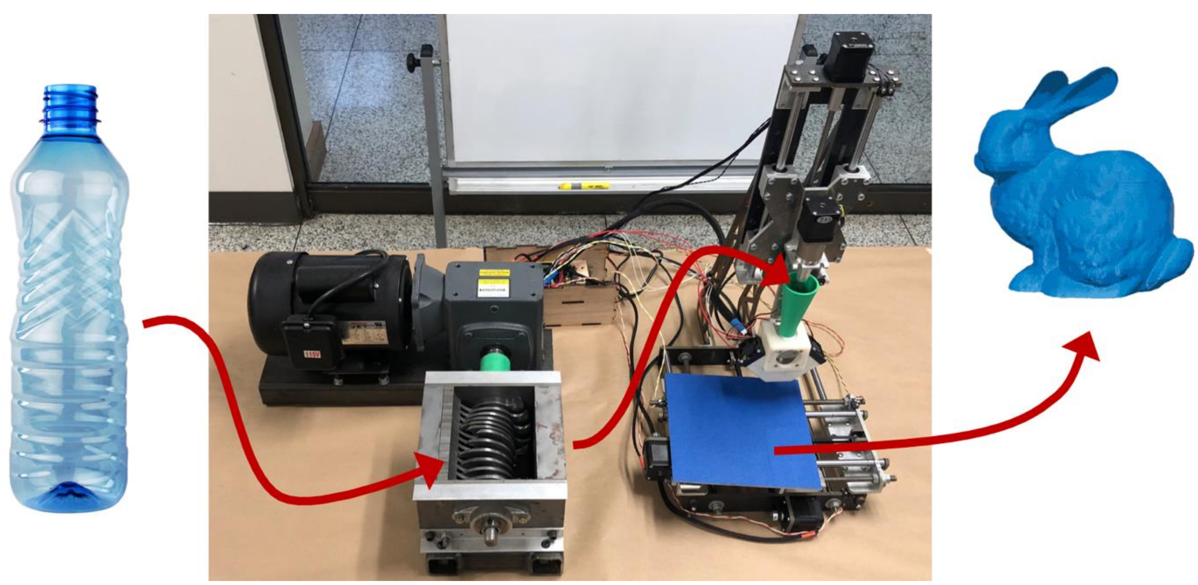
Makerspaces are powerful physical as well as social spaces for prototyping and learning. These spaces, across universities and communities nationwide, allow any individual with a desire to do so to design and manufacture their ideas. Makerspaces can also be instrumental in cultivating the ideas of sustainability and directly tying them to manufacturing practices. We envision makerspace playing two key roles in sustainability. First, of providing a center for innovation, where sustainable technologies are developed, nurtured and brought to market. Second, of serving as a space where any individual can create, and as such allowing us to democratize manufacturing and empower individuals and communities with the ability to produce their own goods.

To explore these ideas, we developed a project surrounding 3D printing of recycled plastics in the Aero Maker Space at Georgia Tech. We designed, built, and are operating a custom 3D printer which takes as its feedstock old plastic which is in turn shredded, extruded, and manufactured into a new product. Standard fused deposition modeling (FDM) 3D printers use tightly controlled filament as their feedstock. Our printer is designed to take raw pellets of plastic and convert them straight into 3D printer parts while completely skipping the filament manufacturing process.



Raw plastic is fed into the shredded on the left which is constructed from several interlocking waterjetted steel pieces. Our design is based on the shredder created by Dave Hakkens from Precious Plastics (preciousplastic.com). A perforated metal grating is used to filter the correct size of shredded plastic to feed into our machine. The 3D printer is an original design that is also constructed from waterjetted steel pieces and readily available off the shelf components. The printer's extruder is unique because it can use a variety of plastic materials in composition, pellet size, and melting temperature.

Designing, building, and testing our 3D printer for recycled plastics at the Aero Maker Space in the school of Aerospace Engineering has generated a great discussion in the space about sustainability within maker spaces and how to best use our resources for 3D printing. The printer continuous to be improved and fine tuned to find optimal print parameters for a number of different plastics.

SLS ESSC Blog Post

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I have started my SLS fellowship on Energy Systems for Sustainable Communities with a clear goal in my mind: I wanted to assess the climate mitigation potential of biomass production for energy use in the Southeast and possible climate change impacts on the supply.

The goal was driven by several factors.

I am an environmental economist and my main area of research is the economics of climate change. My research focuses on the use of economic models to study how the optimal technology mix in the power sector and the optimal use of land are affected by climate mitigation policies (mitigation) and by climate change (impacts and adaptation). Currently, one of my project focuses on assessing climate change economic impacts on land (productivity, fire risk, biomes migration) under alternative climate scenarios to make the supply of land truly endogenous and then estimate forest mitigation potential in terms of biomass production and carbon sequestration. While I was working on this project, I started to be more and more interested in regional and local impacts of climate change on land; in particular, I was interested in assessing how climate change is likely to alter biomass supply in the South East. The South East represents a very stimulating case because its socio-economic and environmental characteristics (increasing population, main woody biomass exporter). A step further involved the interactions of the energy systems with other key infrastructure systems, particularly land and water. Again, the South East is a perfect case to assess these interactions being the stage of the water wars for years. Finally, the interdisciplinary nature of my research makes important the collaboration with colleagues from colleges and units across campus and I thought the fellowship would have facilitated this aspect.

Well, my plan changed during the course of the fellowship. After visiting the Living Building and talking with the experts, I decided to focus on the potential emissions reduction of the Living Building and the social cost of carbon. I thought that the living-laboratory nature of this building should be explored more from a social scientist prospective and I am very into the idea of using it as a case study for my Climate Policy course next semester. I plan to have two teams working on two projects on the Living Building and its climate mitigation potential. The first project will work on estimating avoided CO_2 emissions of electricity consumption in the Building by comparing it with similar buildings (at Tech) in terms of use and size but with a more conventional source of electricity. The second project will focus on estimating the carbon footprint of the material used in the building and compare it with other materials (for example: different wood types and concrete). Then, team will assess the economic costs and analyze the policy implications of using certified wood relative to a different one (Southern pine) or different material (concrete).

I hope this project will present a great learning experience for my students.

Smart Mobility for Living Buildings

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The SLS' Fall 2017 Energy Systems for Sustainable Communities (ESSC) Fellows Program addressed the significant role of communities in enabling and maintaining sustainable energy systems. The Social Circle's Solar Farm, the Southface Energy Institute, and the Kendeda Building for Innovative Sustainable Design—the first Living Building Challenge (LBC) certified building in the Southeast, to be built at Georgia Tech[1]—are all examples of forward-thinking sustainability and equity being pursued in the Southeast. The LBC, an international sustainable building certification program, promotes advanced building sustainability in seven performance areas: place, water, energy, health& happiness, materials, equity and beauty[2]. While the LBC and the Kendeda Building address sustainable infrastructure, a larger sense of sustainability includes the nexus of transportation and infrastructure. From this larger perspective, pursuing sustainable mobility in parallel with building sustainability is fundamental to a

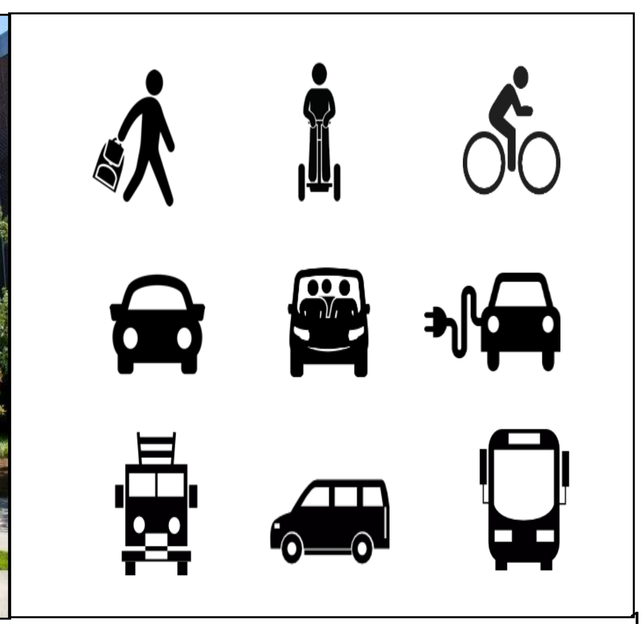

Figure 1: Current Georgia Tech Campus Directory, which can be leveraged to instrument and place interactive *Smart Mobility Signage*, providing information on sustainable intra-campus and intra-city mobility

holistic Net Zero energy system for the Georgia Tech community.

Herein, we advocate for the eighth, complementary performance area of transportation and propose *Smart Mobility*, a sustainable and equitable transportation system supporting travel to and from the Living Building. Due to both the emergence of autonomous and connected vehicles[3,4], and the ubiquity of mobile applications, it is anticipated that the merging of both can yield new forms of sustainable, socially-networked transportation systems that significantly offset usage of fossil fuels while providing convenient and efficient mobility solutions for people. We envision that a Smart Mobility system be built alongside the erection of Georgia Tech's first Living Building. The blog addresses high- level aspects of such a mobility system, suggesting key technologies and important considerations. We anticipate follow-on efforts to engage key Georgia Tech stakeholders and socialize Smart Mobility as an important component of any future, campus-wide sustainability and equitability initiative. Transportation accounts for a significant portion of greenhouse gas (GHG) emissions[5]. In addition to advancing the contribution of our transport system to a more sustainable and equitable future for the Georgia Tech community, we need to ensure that the mobility demand at Georgia Tech is met effectively while leading to a minimized carbon footprint for both inter-building (between campus buildings) and intra-city trips (to and from the city-campus). This requires a fully integrated system leveraging technology advancements that streamline Smart Mobility[6]. One such envisioned system might include a developer

[1] http://livingbuilding.gatech.edu/s

[2] https://living-future.org/lbc/

[3] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

[4] https://www.cbsnews.com/news/toyota-research-institute-ceo-gill-pratt-on-new-frontier-for-auto-industry/

portal (backend) and a customer dashboard (front-end) featuring RFID-enabled, interactive, informational Signage (see Fig. 1), linked to a mobile application service that informs the community of alternative mobility choices based on desired origin- destination buildings. The information provided for each trip could include available transport options (e.g., rideshare, Zipcar, smart autonomous shuttle services such as an "Autonomous Tech Trolley", etc.), along with travel time, cost, comfort level, energy expenditure, GHG emissions, and an overall sustainability score for each choice. The Living Mobility Signage will offer alternative incentives to encourage greener mobility choices to become predominant modes of transport within the community, with the vision of achieving net-zero mobility on campus. This includes more active modes of transportation such as walking and cycling.

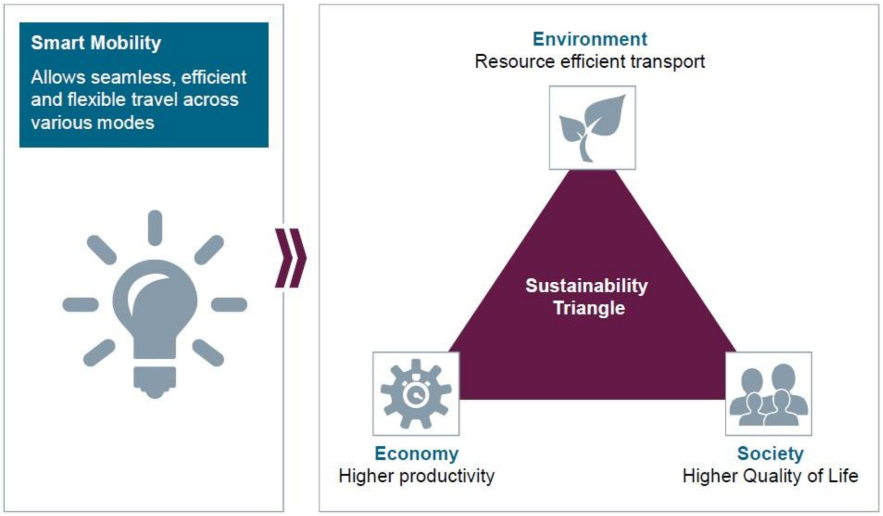

Figure 2: Smart Mobility is a powerful tool to achieve a more sustainable future[1].

The proposed Smart Mobility system (see Fig. 2) has the capacity to integrate other sustainability dimensions such as safety, equity, good health and well-being, as well as green infrastructure in response to the UN's Sustainable Development Goal of building resilient infrastructure (SDG 9), sustainable cities and communities (SDG 11), and responsible consumption and production (SDG 12), in addition to enabling decisive actions on energy (SDG 7) and reducing greenhouse gas emissions (SDG 13). By pursuing Smart Mobility at Georgia Tech, it is important to leverage existing, or develop new, competencies in connectivity, autonomous vehicles, data analytics, user experience, and equity. These competencies are needed to address the key Smart Mobility issues, which we outline to be the following:

- Mobility data: Gather and analyze a driver or a carpooler's background information (home address, work address, preferred transportation mode, preference for saving time versus emissions, etc.) and intent (destination address, timing), and other considerations.

[5] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[6] http://www.vt.bgu.tum.de/fileadmin/w00bnf/www/VKA/2014_15/150212_Smart_Mobility_v5_TUM.pdf

- Mobility behavior: Compare individual driver/user performance across the standard or electric vehicles to design incentives to encourage shared mobility.
- Mobility analytics: Segment transportation by different levels of shared mobility to accurately measure drive times and maximize productivity.
- Sustainable mobility trends: Evaluate regional habits and transportation patterns to simplify asset allocation, aiding expansion into new communities and improving service in existing areas.

In summary, we envision Smart mobility to be a paradigm shift to a more flexible and multi-modal transportation system – e.g., from a "mono-modal" transportation system to a multi-modal system with high flexibility, convenience, and equitable distribution of resources fitting into the wider vision of Smart Services (see Fig. 3). Smart Mobility will be a powerful tool to achieve a better future: more time for users outside of traffic, flexibility to use the best-fitting transportation mode, lower cost for the individual and the society, better and more equitable utilization of transport assets, lower consumption of valuable resources, and a cleaner and more sustainable future.

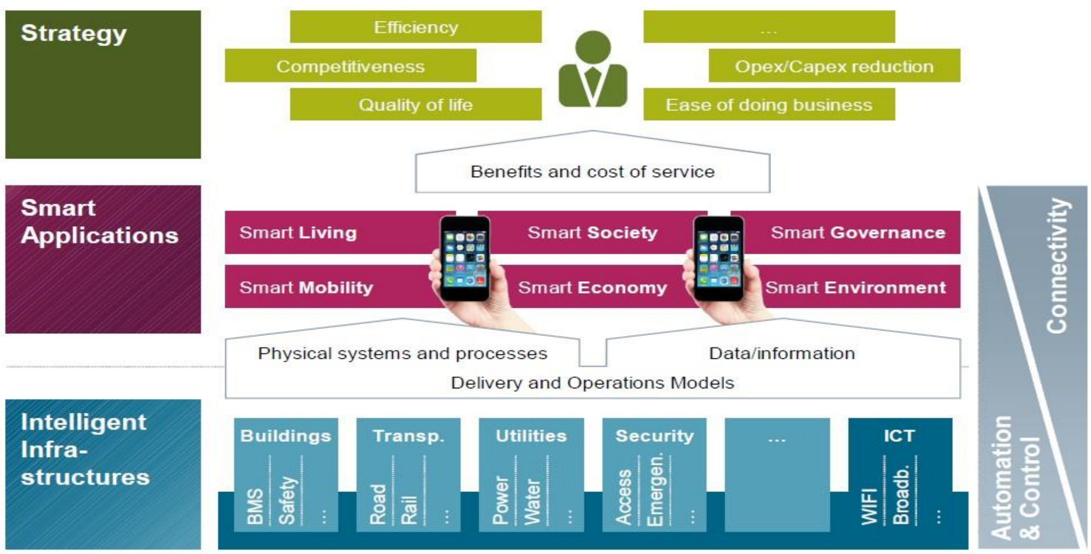

Figure 3. A smart mobility system should enable Smart Services[7] for diverse user needs inside and between living buildings.

The Economics of Green Buildings and the Expected Impacts of the Kendeda Living Building at Georgia Tech

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What is a Green Building and Why Build Green? What are the economic justifications for building a Living Building? What are the expected benefits of building a Living Building? And what can experience with other green building programs tell us about the expected outcomes of the Living Building at Georgia Tech?

1. What is Green Building, and Why Build Green?
   Green Buildings are defined by a holistic multi-dimensional approach to building, considering the lifecycle impacts of a building including construction, operation, and deconstruction, as opposed to a unidimensional approach, such as a singular focus on energy efficiency. Green building is thought to have a wide range of benefits for society and for the building occupiers. Improved energy and water efficiency are the more obvious benefits, but green buildings have improved indoor air quality; employees are more productive and miss fewer days due to illness; and high-quality employees are easier to hire and retain. Green Buildings also provide a number of benefits to society including, but not limited to, reduced construction waste, the use of environmentally friendly materials in construction, and improved storm water retention and treatment (Matisoff, Noonan, and Flowers 2015).

2. What are the economic justifications for building a Living Building at Georgia Tech?

   Given the built environment is a major source of disruption to ecological and environmental systems, market intervention is required to provide the appropriate incentives for green building activity and preserving the function of these natural systems. Certification and labeling programs for green building – such as the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) or the International Living Future Institute (ILFI)'s Living Building Challenge (LBC) incentivize the private production of public goods. These programs work by supplying a marketing benefit in exchange for investing in additional building upgrades that may have not been cost-effective without the marketing benefit gained by certification (Matisoff, Noonan, and Mazzolini, 2014).

   Economists consider three types of "market failures" that cause the market to systematically under-invest in green building technologies and practices. These include search and transaction costs, information asymmetries, and externalities associated with building. Programs designed to increase green building practices can be understood as an effort to reduce barriers to green building and to better align their private costs with their social costs.

Search and transaction costs refers to the idea that using advanced energy and environmental technologies associated with Green Building are costlier for builders and contractors to pursue because they are less familiar with these building techniques, which also have uncertain benefits. Information costs associated with green building procurement, including the poor understanding of the potential costs and benefits associated with the technologies themselves, deter builders and contractors from investing in green building practices and technologies. By undertaking the Living Building, Georgia Tech is supplying information on the procurement process, lowering the costs for future buildings. Once the Living Building is built, potential builders and contractors, will have improved information about the performance of the technologies and practices included in the building, reducing costs and risks associated with adopting new technologies and practices. See Figure 1 below.

Information asymmetry refers to the idea that builders and building owners often have a better understanding of the construction process, design, and performance characteristics than owners or occupants of the building. Building qualities, such as lighting efficiency and indoor air quality, are difficult to detect or verify before purchase or lease. Some green qualities like sustainable material sourcing and construction waste treatment are impossible to observe for the building occupant. Economic theory suggests that the difficulty in detecting information about a building can lead to a "market for lemons" in green building (Ackerlof, 1970), where low-quality buildings can crowd out high quality (green) buildings. Certification serves to verify difficult-to-observe building characteristics and improvements to building performance and allows building owners to internalize the value of those investments. See Figure 1 below.

(Negative) Externalities refers to the idea that buildings often impose additional costs on society associated with their building construction, operation, and deconstruction that are not borne by the building owner or tenant. For example, the construction process can generate significant construction waste and impact air and water quality, and building operation produces unpriced social costs related to energy use and storm water runoff, impacting air and water quality. Green building programs, such as the Living Building Challenge, seek to reduce negative externalities in the building lifecycle. Participants in these programs undertake costly private actions to produce public goods and to certify operational improvements, thus internalizing the social costs of their actions. Membership in this green building "club" demonstrates to stakeholders that club members have undertaken certain actions that reduce the negative externalities of buildings (Potoski and Prakash 2005).

3. What are the expected benefits of building a Living Building?
   The benefits to building a Living Building at Georgia Tech can be classified into several categories:

   First, there are the direct benefits of the technologies employed themselves. The Living Building is expected to be net energy and water positive – that is it will produce more electricity and treat more water than it uses. By using sustainable materials and through innovative design, it is expected to be a place people want to work and inspires creativity and productivity. In addition to some benefits that are direct to Georgia Tech, such as reduced electricity consumption, reduced water consumption, or improved research output, this provides community/public benefits as well, such as improved air and water quality.

Second, there are benefits associated with certification. While Georgia Tech will not lease space to customers or clients, Georgia Tech experiences a number of reputational benefits associated with certification. Certification communicates to stakeholders, such as students, employees, potential donors, and the Atlanta and Georgia communities that Georgia Tech is an innovative, sustainable institution, dedicated to being a leader in the sustainable community movement.

Third, by being an early adopter of the advanced energy and environmental technologies that are incorporated into the Living Building, Kendeda and Georgia Tech are lowering the costs for future adoption of similar technologies and practices. This includes supply side and demand side effects. On the supply side, by being an early adopter to the Living Building Challenge, Georgia Tech incurs costs associated with implementation of a new program including establishing new supply chains and overcoming procurement difficulties. A new certification program inevitably involves increased challenges and costs associated with documentation and verification of performance. Significant investments in human knowledge and know-how need to occur in order to reach certification. By laying out a path to achieve Living Building certification, Georgia Tech reduces costs for future adopters and increases the probability that other related organizations undertake similar efforts. On the demand side, Georgia Tech’s investments in advanced energy and environmental technologies allow potential future adopters to have a better understanding of the costs and benefits associated with these technologies. Specifically, by sharing information with interested parties, either through workshops, seminars, or conferences, stakeholders involved with the Living Building are able to directly convey valuable information on specific implementation and operational strategies for success. Figure 1 below describes these impacts graphically.

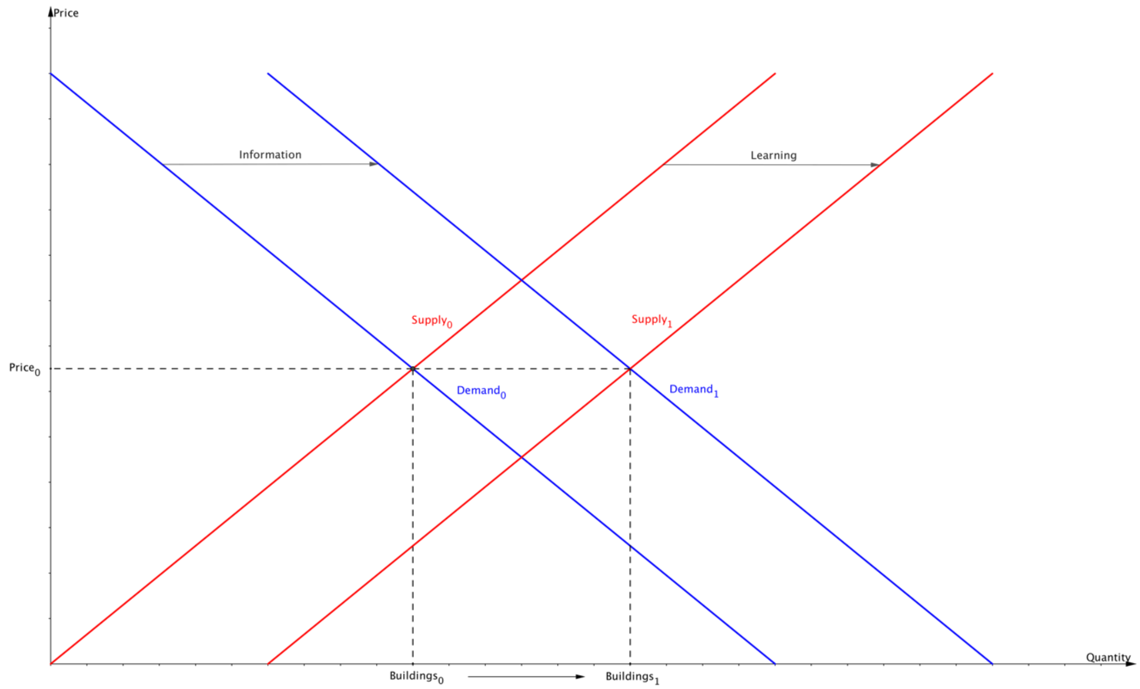

Figure 1: The Impact of the Living Building on the Green Building Market. The original green building market equilibrium is characterized by a green building real estate value ($Price_0$) and the number of green buildings currently in the built environment ($Buildings_0$). The Living Building is expected to affect the market for green buildings through both demand and supply-side channels. On the demand side, reducing information asymmetries resolves uncertainty and increases demand in the market for green buildings. This leads to a rightward shift of the demand curve (blue line) from $Demand_0$ to $Demand_1$. On the supply side, reducing search and transaction costs through learning-by-doing improves the productivity of green building suppliers and increases the supply of green buildings in the market. This is illustrated graphically as a rightward shift of the supply curve (red line) from $Supply_0$ to $Supply_1$. Because the impact of the Living Building on the green building real estate price is ambiguous, we draw the demand and supply-side shifts in such a way as to maintain the original value of green buildings. However, it is also quite possible that the increase in demand and economies of scale lead to lower prices over time. The impact of the Living Building on the overall size of the green building market is easy to determine graphically. We can expect these positive impacts to lead to more green building activity, as labeled by the change in equilibrium size of the market from $Buildings_0$ to $Buildings_1$.

4. What can experience with other green building programs tell us about the expected outcomes?

   Much of the research done on Green Building has been conducted in the context of LEED, for which there are tens of thousands of certified buildings in the United States. By contrast, the Living Building Challenge is well-beyond LEED, based on the requirements, but only several dozen buildings have been certified. However, research on

LEED tells us that LEED buildings are far more energy efficient than their traditionally built counterparts (Asensio & Delmas, 2017). The certification system in LEED and marketing benefits associated with certification cause firms to invest more in energy and environmental technologies than they would otherwise (Matisoff, Noonan, and Mazzolini, 2014). Over time, certified buildings have achieved higher levels of certification, and firms have invested increasingly in advanced energy and environmental technologies, suggesting that the benefits of advanced energy and environmental technologies have increasingly outweighed the costs, or that the costs associated with employing greener technologies have been reduced (Research in Progress). This trend also suggests a role for certification programs in facilitating market transformation. Finally, the presence of a LEED pilot project appears to increase the likelihood of an additional LEED building in that county by roughly 12% each year (Research in Progress). This seeding effect is in addition to increased green building that takes place as a result of the momentum of having a larger installed base of green buildings.

Based on past research, it is reasonable to expect that a Living Building at Georgia Tech can have multiple pathways to effectiveness. We should expect it to reduce energy and water impacts at Georgia Tech. It is expected to be a desirable place to occupy, with potential creativity and productivity benefits. We should expect it to increase Georgia Tech's reputation as an innovative and sustainable place to live, work, and learn. And finally, we should expect that it increases the probability that others pursue Living Building certification in the Atlanta region in the future, as this project should reduce costs associated with pursuing certification while improving the understanding of the benefits of technologies and practices in the building.

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SLS ESSC Blog Post

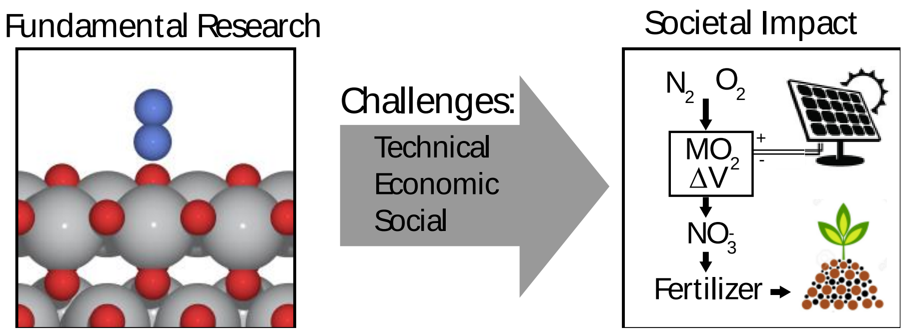
Andrew Medford, Assistant Professor
School of Biochemical Engineering

The SLS Fellows program on Energy Systems for Sustainable Communities (ESSC) was a fascinating experience in truly interdisciplinary discussions. My own research focuses on establishing atomic-scale computational models of catalytic systems for energy conversion and fertilizer production, and I joined the fellows program to get some perspective on how my fundamental work fits into the broader picture of energy systems and policies. I came in with an awareness of the large gap between quantum-mechanical studies of catalyst surfaces and pracical systems, but I quickly realized that I had underestimated the challenges - particularly the non-technical ones. The ESSC fellows program gave me a much broader picture of the landscape of sustainable energy research, and connected me with a diverse group of researchers working on all aspects of the challenges that must be overcome to achieve sustainable societies.

As a chemical engineer I was particularly interested in how energy systems can enable the chemical transformations necessary to produce sustainable communities. In particular, one focus of my work is on understanding electrocatalytic and photocatalytic transformations that enable direct production of chemicals from sunlight or electrical energy. These systems are highly relevant to sustainable communities because, unlike most chemical processes, they operate at small scales and low temperatures and pressures with sustainable energy sources. The development of such processes has the potential to enable communities to manufacture their own chemicals such as fertilizers and fuels rather than relying on large, centralized plants that are typically driven by fossil fuels and controlled by large external entities. The potential benefits of electrochemical processes are relatively well-known in the chemical engineering community, but I learned from the ESSC program that the concept of solar or electrochemical fuels and fertilizers was not a familiar concept to non-engineers. From this I learned that there is an opportunity for chemical engineers to more efficiently communicate technical knowledge to other stakeholders who are working to develop sustainable communities.

Electrochemistry is a technical concept that I was more familiar with than many ESSC participants, but I learned that the converse was also true: there were many non-technical (and some technical) concepts that other ESSC fellows were experts on, but I had never considered. One example of this occurred after the talks from Southern Company and the Georgia Public Service Commission, where I learned that power consumption data is not made available to researchers, creating a significant impediment to understanding and optimizing energy systems. From a technical standpoint it seems like a simple solution: power companies that receive government subsidies should be required to provide usage data to the public. Of course this technically simple solution is politically complex, leading to an inefficient situation where researchers must collect data from indirect sources to understand patterns in energy consumption. Another perspective I gained from the ESSC program was the idea of social equity as an aspect of sustainability, as discussed during the living building tour. The concept of ensuring that resources are fairly distributed within a community will lead to social sustainability, which is not directly related to engineering, but can be enabled by it. These diverse prespectives gave me a lot of appreciation for the work of other groups on campus, and led to an improved understanding of how and why sustainability is inherently interdisciplinary.

In conclusion, the key insight I gained from the ESSC program was a general appreciation for the value and challenges of working across academic silos to solve the complex problem of energy in sustainable communities. As engineers it is easy to become hyper-focused on solving a specific aspect of a technical problem and lose sight of its societal context, but programs like ESSC help keep everything in perspective. Conversely, these programs provide a valuable opportunity for engineers and scientists to share technological advances that may lead to improved sustainable communities in the future.



The Causes, Consequences and Strategies for Diminishing Urban Heat Island Effect in Atlanta

Arkadeep Kumar, Graduate Student Researcher
The George W. Woodruff School of Mechanical Engineering

Kerri Metz, Research Associate I
Energy, Policy, and Innovation Center

Marcela Moreno, Research Associate I
Strategic Energy Institute

Over the Serve-Learn-Sustain Energy Systems for Sustainable Communities fellowship, our team was able to explore our own interests in energy and sustainability while connecting with others on campus. Marcela's undergraduate background was in history and sociology, with a keen interest in the history of medicine and public health. She recently finished her Masters in City & Regional Planning at Georgia Tech where her research interests focused on the built environment, climate change and human health. Kerri's background is in energy policy and renewable energy implementation, with a Masters in Environmental Management. She specializes in global environmental change with a particular interest in low-carbon energy adoption and policy pathways. Arkadeep's background is in Mechanical Engineering, sustainable energy, with his Ph.D. research in manufacturing silicon wafers for solar cells which have higher mechanical strength and hence more reliable. He is also interested in how technology and people interact with each other, especially with the recent developments in Internet of Things (IoT), and smart sensors for humans and the environment. The fellows program brought them together over coffee in Clough Commons to mold their different interests and expertise into a project that otherwise could not be completed individually. Over this meeting, a common thread in our research was a need to take our academic strengths and use them to hopefully make positive and impactful community change.

Urban Heat Island

Urban heat island effect describes the phenomenon of urbanized areas being hotter than rural areas. Its effects can include increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and morality and water quality. According to the EPA, the annual mean air temperature of a city of 1 million or more can be 1 to 3 degrees C warmer than its surroundings, and during the evening, the difference could be as high as 12 degrees C. The causes of urban heat island include (but are not limited to) low amounts of evapotranspiration due to less vegetation, absorption of solar radiation due to low albedo, hindrance to the flow of air due to higher rugosity and high amounts of anthropogenic heat release. (Nuruzzaman, 2015). The mélange of factors include the materials and layout of the built environment, as well as the human use of electricity and transportation. The health risks of UHI vary on the season, and are particularly amplified during the summer. These effects are outlined in *Figure 1* below.

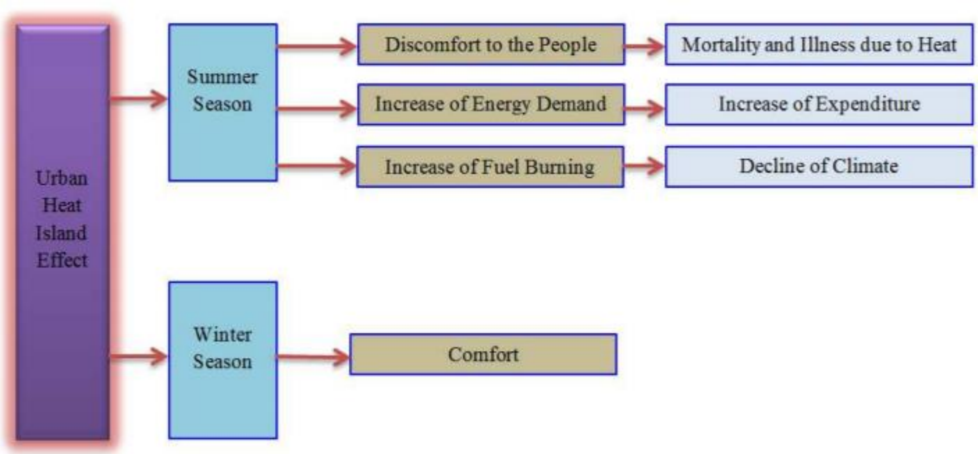


Figure 1. Urban Heat Island Effects (Nuruzzaman, 2015)

Of particular note to our research, UHI is not only caused by anthropogenic heat release (largely from energy consumption from buildings and transportation), but also exasperates the need to rely on these systems to achieve a level of human comfort. This feedback loop of actions and consequences resonates to amplify the effects of UHI, and the aim of our research is to mitigate the anthropogenic causes.

Behavioral change theories
The UHI effect largely stems from high levels of energy consumption in urban areas. Therefore, the most direct means of combating UHI is to encourage more efficient or decreased energy usage through sustainable behavioral change. Given that 40% of energy consumed in the US in 2015 was utilized in for commercial and residential lighting, heating and cooling, the ability to enact and maintain changes in an individual's energy consumption can result in significant reductions in greenhouse gas and pollutant emissions. One of the greatest challenges to achieving such reductions however, is the maintenance and upkeep of sustainable behaviors long term [2]. There is an array of strategies to encourage a commitment to behavioral change, with the seven most prominent including:

1) Making sustainable behavior the social norm
2) Emphasizing personal impact and relevance
3) Displaying and making all information readily available
4) Encouraging mindfulness and realistic goals
5) Creating opportunities for effective change and actions
6) Align changed behavior with other actions and events
7) Create realistic goals and challenges [3].

The overarching finding however, is that sustainable behavioral change is most enduring when sustainable action is the path of least resistance or most appealing choice. Although changes to policy are typically the most effective means of achieving widespread social and behavioral change, the adoption of personal changes to lifestyle and energy use can still have broad and meaningful impacts to combating climate change.

There are several overarching theories as to what most effectively explains the success or failure of behavioral change, but for the purposes of our study we will be utilizing the Transtheoretical Model, or the Stages of Change theory, as it emphasizes the role of individual decision-making and movement towards intentional change. In this framework, behavior and habits are not separate actions, but rather movements within a cyclical process where each action mirrors the actor's current stage. These six stages (which can be seen in *Figure 2*) are: Pre-contemplation, Contemplation, Preparation, Action, Maintenance, and Termination. As each actor and decision-maker moves through the various stages, there are varying strategies that can catalyze movement to the next stage and ensure the endurance of a behavioral change.

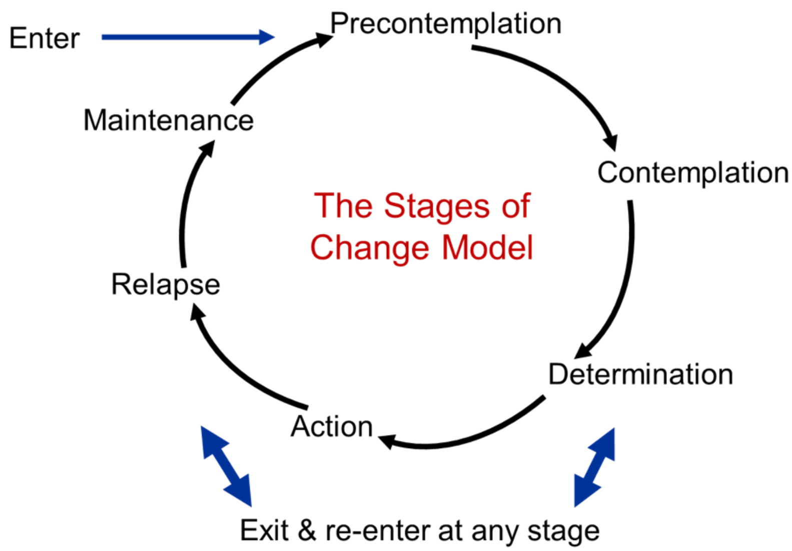


Figure 2. Transtheoretical Model (Stages of Change)

Within the context of encouraging behavioral change as a means of diminishing Atlanta's UHI effect, we propose a Transtheoretical Model that employs all of the seven above strategies within the Model's framework. We will start by raising on-campus awareness of the causes and effects of UHI through informational campaigns, pamphlets, and readily available online information. Through this educational platform we further hope to encourage an emotional arousal about the personal relevance that UHI can have on wellbeing and health, while also emphasizing the feasibility and importance of individual change. Moreover, in order to make sustainable behavior the social norm, we will monitor building conditions and employ low-energy use or energy efficient materials. As a means of creating opportunities for effective change, we will lead and develop initiatives on campus that provide information on those lifestyle habits that have the greatest levels of energy consumption among students and faculty. Encouraging the social popularity of sustainability by making energy efficiency both the path of least resistance and rewarding (both materially and intrinsically) will allow such a behavioral change to maintain itself into the future. The key to maintaining behavioral change however, will be in rewarding positive behavior while re-engineering our campus and buildings to have reminders to engage in sustainable behaviors or impediments to engaging in wasteful energy consumption.

Through these steps and data obtained from Georgia Tech's Living Building, we hope to measure the use of a building's energy efficient systems and other conditions (discussed in detail below) that can be monitored within the campus buildings. These measurements and data will be used as a proxy for gauging a reduction of UHI and combating climate change.

Interventions for Sustainable Behavior

We propose some interventions on the lines of encouraging sustainable behavior with regards to usage of energy and water, which is expected to mitigate the urban heat island effect, and work towards the Sustainable development goals set by the United Nations (UN SDGs). One of the oft heard cliché lines about bringing change to something is to first measure it. Hence we would have to employ measurement systems for our usage of energy and water, as well as monitor our behavior, along with thoughtful reflections - which can bring positive behavior change. We have several possibilities for interventions:

1. Monitoring the urban heat island effect

Monitoring of the heat island can be done by measuring air temperatures and (the more effective) surface temperatures [4]. The study at the University of Wisconsin Madison installed numerous temperature and humidity sensors on street lights and utility poles, to measure the heat island effect [5]. Similar sensing strategies can be employed for the GT campus and the location of the Living building.

For the GT campus location, we hypothesize that the ground based sensors for temperature and humidity would be most useful. Other sensing methods include satellites and aircraft, and ground based sensing technologies.

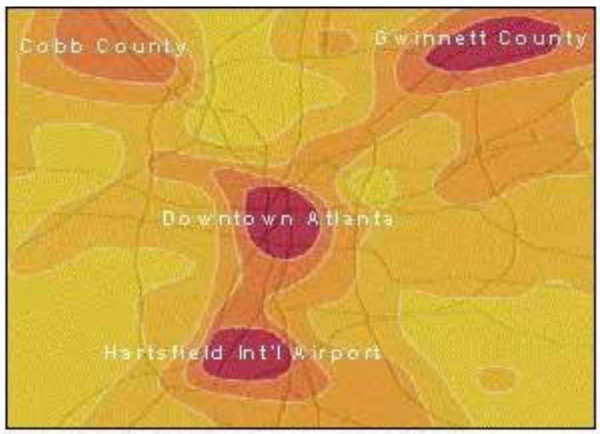


Figure 3 shows satellite imagery of the urban heat islands for the city of Atlanta to be concentrated around the downtown and midtown (Georgia Tech) and the Atlanta airport [6].

2. Improvements in building materials and impact on behavior

Using technologies such as smart glass or electro-chromic glass, which can change the amount of sunlight entering through large windows and walls (and if there are glass walls) of the building, and the amount of energy needed to cool (during summer) and keep warm (during winter) can be reduced. The glass technology consists of metal oxide coatings, which can change color based on the voltage applied, by the flick of a switch [7]. Some of these technologies have now undergone enough research and development that they are commercialized by leading building material and glass companies, and used in many commercial buildings. While the control of smart systems could be done by flicking a switch, an even more efficient system for reducing energy usage is by using sensors to give feedback how much light or heat in the room is present, and use that input to control the technologies using data-driven methods and Internet of Things (IoT).

3. Sensing and monitoring of energy usage of individuals

With use of smartphones and smart devices/wearables for a majority of users of the building, we can encourage them about sustainable energy use by targeted messages, which can be as simple as asking them to turn of lights as soon as they leave to exit the building (with use of proximity sensors, which can connect with the internet and smart devices). Other possible systems include tracking the energy usage and alerts certain appliances are consuming more energy [8]. Other energy consumption analyzers are available to monitor energy usage, record data for a number of meters (gas, water, electricity) and put into a database [9]. While some of the systems have sensors which can be plugged in to the electrical panel or the breaker box of the building, others collect the data and use learning algorithms to inform the human users about the energy usage patterns of appliances over time [10].

With the above possible interventions, we can analyze and decide the systems which are more likely to affect behavior change, and target them. With these interventions, we expect human behavior to reduce the use of energy and water, and thus encourage sustainable practices - which will ultimately reduce the urban heat island effects. Apart from the energy efficient appliances, and monitoring of energy use to reduce wastage, to mitigate urban heat island effect, some of the other activities which can be encouraged are tree cover increase, installation of green roofs and smarter building materials [11]. Raising the awareness about personal behavior’s effect on usage of energy and water is also important, which can be done by outreach activities. Outreach also helps in getting the community involved in all the stages of implementing the behavior change project. Incorporating the feedback of the community helps in getting their support and buy-in.The feedback of the community also helps in customization of the interventions, which will translate to more chances of the success of the project.

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Repair-Making-Sustainability

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George W. Woodruff School of Mechanical Engineering

<u>1. Buzz's bike</u>
Buzz was very anxious today. He had just wrecked his bike and it looked like one of the gears had been broken. The bike could not be used in this condition and it was not just any bike. It was a 1949 Schwinn B6 given to him by his family, originally owned by the legendary Bobby Dodd. This bike held great sentimental value and was simply not replaceable.

Worse, this meant he now had to walk to classes and events. While normally not a big deal, he had back to back classes on opposite ends of the campus this semester. Easily a 20 minute walk with only 10 minutes between classes. Fortunately, it was about to be spring break, so he had a week to assess and correct the situation. The first step would be finding some help, but where on the Georgia Tech Campus?

<u>2. Georgia Tech Campus</u>

Georgia Tech is an urban campus at the heart of midtown in the city of Atlanta, Georgia. The school has a mix of undergraduate and graduate students in masters and doctoral programs, with a research focus. Many of its programs are the top ranked in the country including its Undergraduate Biomedical Engineering and Industrial Engineering programs. The campus is over 400 acres and walking from one end to the other can take 25 minutes. As a result, many students typically travel within and around campus on bicycles. There are a number of efforts to encourage riding of bikes, such as bike lanes, lessons by GT police department (GTPD), and free giveaways during events like bike week. There is also a center for sustainability called Serve-Learn-Sustain (SLS), which promotes sustainability in many forms, be it smart cities, or energy efficiency and water usage, and sustainable transportation. There are several initiatives for students which encourage using bikes for transportations. There are bike share programs like BuzzBikes, where one can rent a bike from GT at a price around 50$ per semester, with all the maintenance being done by GT. There is also the newly setup relay bikes program, which uses RFID on chip cards given to the users to help users lock the bikes to the relay bikes rack.

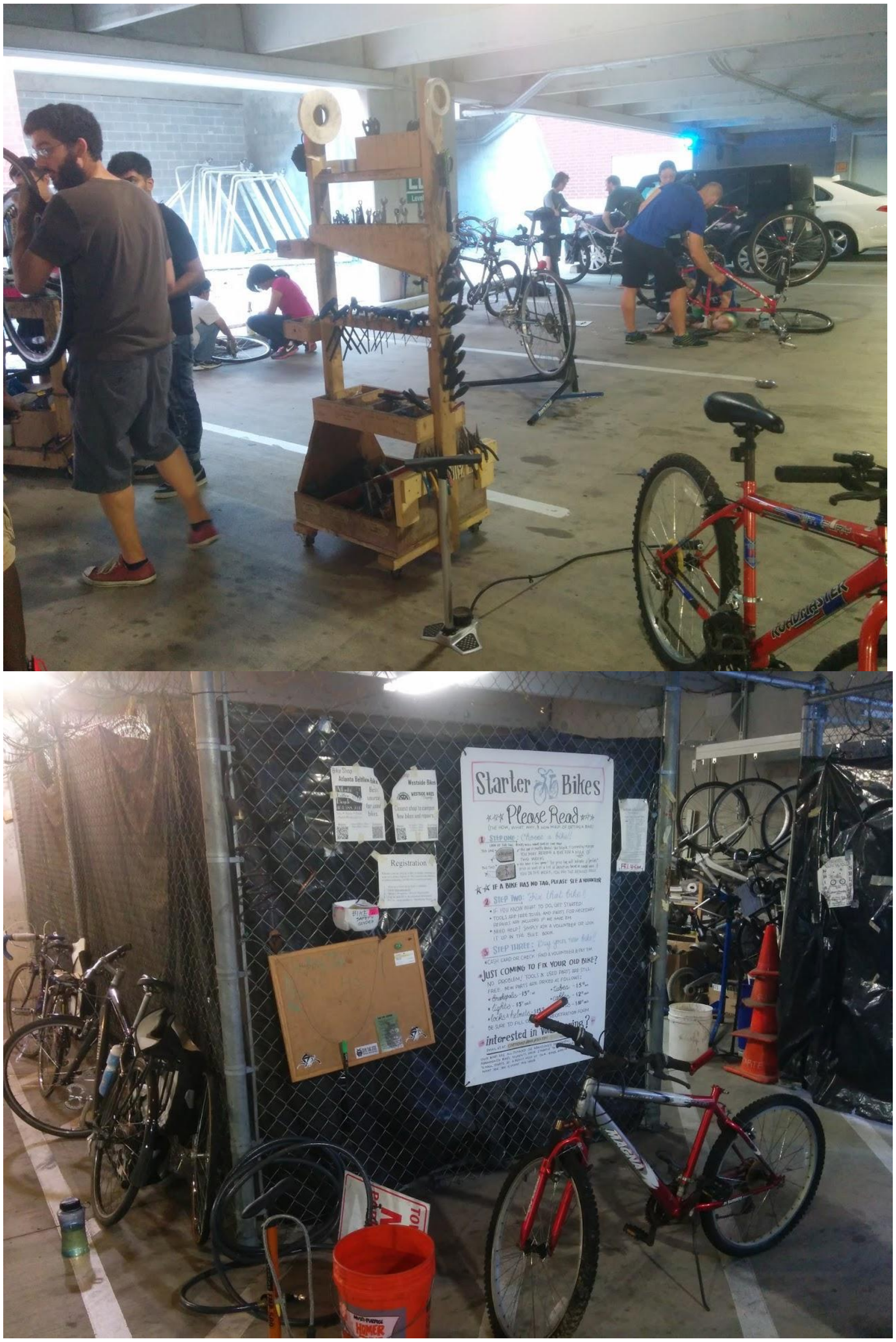
There is an initiative within the campus called Bicycle Infrastructure Improvement committee (BIIC) http://bike.gatech.edu/programs/biic/. One such initiative is to repair their bikes by themselves - called Starter bikes, which meets every Friday 4pm to 6pm on the lowermost parking deck of the CRC. Buzz was going through the Clough commons, when he saw a SLS event on sustainable transportation - he stopped to hear what it is all about. In the event he found a flyer about this Starter bikes just as he was getting worried what to do with the broken part of the bicycle. It was Thursday, so fortunately the next day had the Starter Bikes repair shop open on Friday afternoon, so he decides to visit the repair location after classes.

3. Bike repair at GT:

The bike shop called "Starter Bikes" is one of the initiatives of the Bikes@GT (http://bike.gatech.edu/programs/starterbikes/). It started some years back when some enthusiastic bicycle users found the need to have a repair shop on campus. It is fully volunteer run and referred to as a bike cooperative. They have tools and some parts to fix bikes with volunteers who teach how to fix the bike. If someone does not have a bike, the volunteers also help refurbish abandoned cycles on campus (rounded up by GTPD) or donated bicycles to make them working again. This is a ***reliable and sustainable*** option for students on a tight budget. The access to the tools is free, and the expertise or knowledge is freely shared by the volunteers. The feedback from the volunteers is that they give their time as they are enthusiastic about more people using bikes for transportations. Even though the hours of the Starter bikes are 4-6pm on Fridays, they keep it open till 7 pm or 8 pm frequently for people to finish up the repair work. Sometimes working bikes can be found for purchase - ranging from free to $ 50 or even $ 100, depending on how much repair work is needed. The volunteers are always eager to help the buyer fix the bicycle. They even help the person to store the unfinished repair job if the repair takes more time than one evening. The money from the sales goes towards buying tools and supplies of the Starter bikes. Mostly cash is the method of payment, with option of paying by card on the starter bikes website.

The volunteers also maintain some paperwork, which keeps the registration number of the bikes sold and general finances. They also keep items for sale like helmets, and lights for safety of the rider and bike locks for safe keeping of the bicycles.

(image courtesy: http://bike.gatech.edu/programs/starterbikes/)



(image by Arkadeep Kumar)

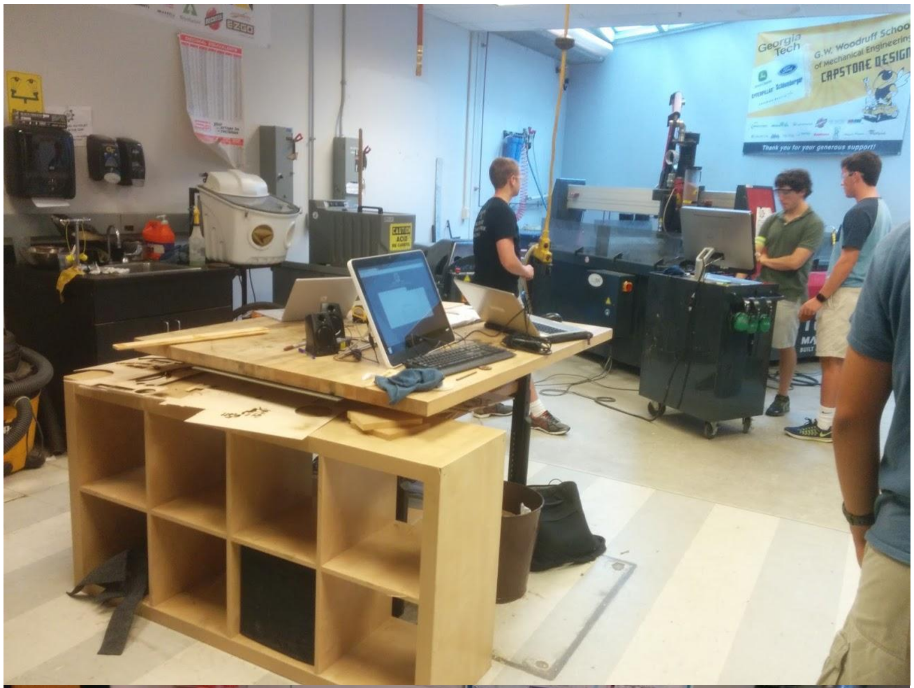
The main volunteers at the Starter Bikes are avid bikers themselves, and were part of the team which made the starter bikes into a regular organization. As mentioned, Starter Bikes is primarily a space with tools which are free to use, to repair old bikes. The volunteers collect old bikes which have been lying unused across the campus. They identify which ones are ‘unused’ by checking the location and signs of use frequently, after a certain amount of time (a semester maybe), they put tags, which is a notification to the owner (with GT police's approval) that the bikes would be removed if the owners are not using it. After 1 month of that notice, GT police helps these volunteers break the locks/cut the locks, and take these bikes to the storage space for old bikes in starter bikes. Thus new supply of used bikes almost come in rolling basis, or mostly 1 month after start of new semester. Students visit starter bikes to repair their existing bikes, or those who do not have a bike, but looking for cheap bike, they try to buy a used bike from here. Prices range from $0-100+ depending on condition, make, brand, how old it is. Used Walmart bikes are very cheap 0-20$ whereas Schwinn could be 80-100$, some Giant/Trek bikes could be 150-200$ (all depends on condition). Prices are decided by the starter bike main volunteers.

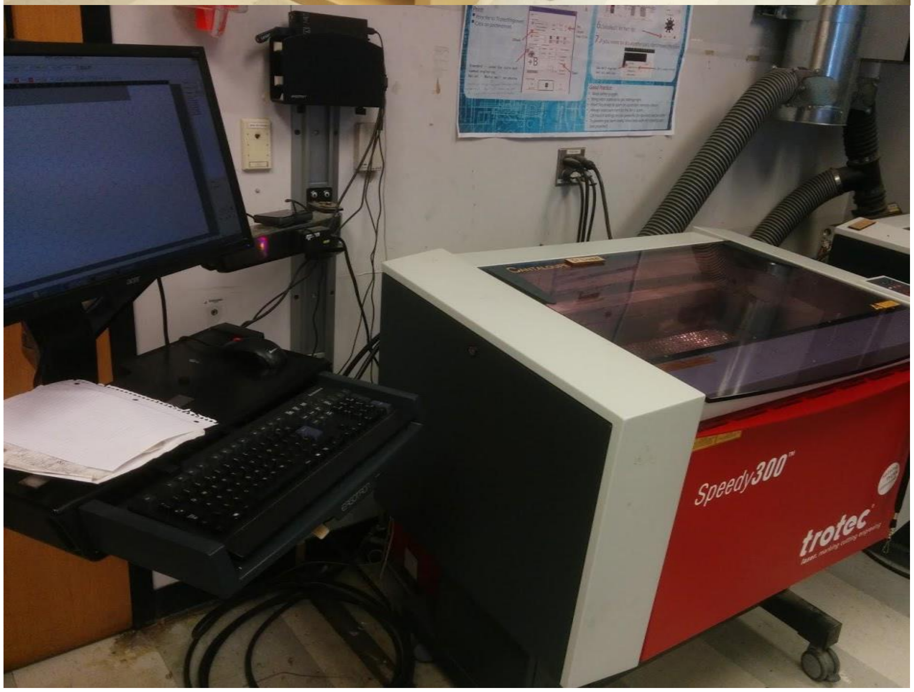
When Buzz rolled into the bike repair with his bike, all the volunteers became excited because they knew Buzz and how special this bike was to him. Buzz showed that one of the handles had a broken part, which was making it difficult for him to shift the gear. Taking a closer look, a volunteer found out that one of the small gears inside the controls of gear shifter appeared to have lost teeth. They quickly looked up online to find a replacement part. However, due to the age this bike, no spare parts could be found. Mike (the volunteer) could see that it would be difficult to use the bicycle without shifting the gear. Buzz was about to give up when Lisa (another volunteer) mentioned a class she had just completed, where she used a makerspace called the Invention Studio. Could this makerspace help Buzz "make" the part he needed? He decided to visit the Invention Studio.

4. Invention Studio makerspace

Buzz remembers about the Invention studio and walks into the Invention studio space. He is greeted by volunteers or Prototyping Instructors (PIs) at the Invention studio, who maintain the space, and help train the students to use the machines to 'make' things. The Invention Studio space started several years ago by the initiative of a few students who had the spirit of making something with their hands. The people who started the Studio have now graduated and left, and only a few of them have continued as graduate students (they had started as undergrads). They told that they want the Invention studio to be a welcoming space for everyone who wanted to make something, as they supported the maker culture, and the spirit of do-it-yourself. It could be work, for research, or simply hobby, and being creative. Over the years they have added rooms and more capabilities.

The Invention Studio in MRDC (Manufacturing Related Disciplines Complex-I) Level I is a set of rooms devoted to makerspace in the Mechanical engineering department in Georgia Tech. The rooms are categorized on the basis of type of working (woodwork, metalwork, and electronics) or type of machines (laser cutter and water jet in one room for sheets of materials/2-dimensional, 3D printers in another room). At any time when the space is open to public/any student, a PI is in charge. The PI helps students get the job done by teaching how to use a machine or tool, recommend settings from experience, troubleshoots the jobs when they fail (e.g.; the laser burns the wood too much), and ensures that safety standards are being followed. The PI has a fluorescent yellow armband to distinguish from the rest of the students (more like the captain on a soccer team). The PIs volunteer their time 3 hours per week (in one stretch or in staggered form of 1 hour each) in return of unlimited and anytime (after-hours apart from 10am-6pm when the studio is officially open) access to the machines and Invention studio area. From prior conversations with the PI, we learned that they give a preference of time slots they are available, and there is a system which automatically matches them with time slots to volunteer.





Laser cutter in the Invention Studio (photo courtesy Arkadeep Kumar)

3D printers in the Invention Studio (photo courtesy Arkadeep Kumar)

MRDC Invention Studio (photo courtesy Arkadeep Kumar)

Buzz found a helpful PI who asked if he had any experience in making things. When he said no, the PI guided him with more advice about how to design the gear on a solid modelling software like SolidWorks. However they soon remembered the scanner which can scan an object and give a 3 dimensional rendering. So they went to the 3D printing room and found the scanner. After scanning they could see some edges had to be corrected (because the bicycle gear part Buzz had brought was broken). After cleaning up the design file, they thought if they should make it by 3D printing or something from metal. It was a 2D object so it could be made by laser cutting from a sheet (if wood or plastic), or by water jet machining (if made from metal). Buzz learned the material selection procedure - based on the usage of the part. They realized they cannot use wood for this load bearing part. They thought they can try with the plastic - and the PI explained that either laser or 3D printing can be used. For better mechanical strength they agreed that using laser to cut the gear would be a good idea. They first cut it out on cardboard to have the prototyping feel of it (picture below as representative), and then they laser cut the gear in plastic acrylic material. The PI explained that Buzz can go into the machining mall and mill out in metal if needed. Buzz said he would try the plastic first anyway, and leaves. Buzz worked for next few days and made the part by 3 D printing or additive manufacturing, taking help from the volunteers at Invention studio (image below).

<u>5. Back with Buzz's bike</u>

Next Friday Buzz goes to the bike repair at Starter bikes on CRC ground floor, and puts in the part, and it worked! Mike, Lisa and the other volunteers listened to Buzz enthusiastically explaining how he made the missing part at the Invention studio. So with the help of the Starter Bikes bike repair, and the Invention Studio makerspace, Buzz was able to save his bicycle, which was valuable to him for being handed down from generations. He was also able to repair instead of scrapping the whole bike, thus displaying sustainable behavior as a consumer. Finally, he was contributing to a community of bike enthusiasts at Georgia Tech who liked sustainable forms of communication like bicycling.

(photo coutesy: http://www.news.gatech.edu/2012/06/25/invention-studio-continues-expansion#more_photos)

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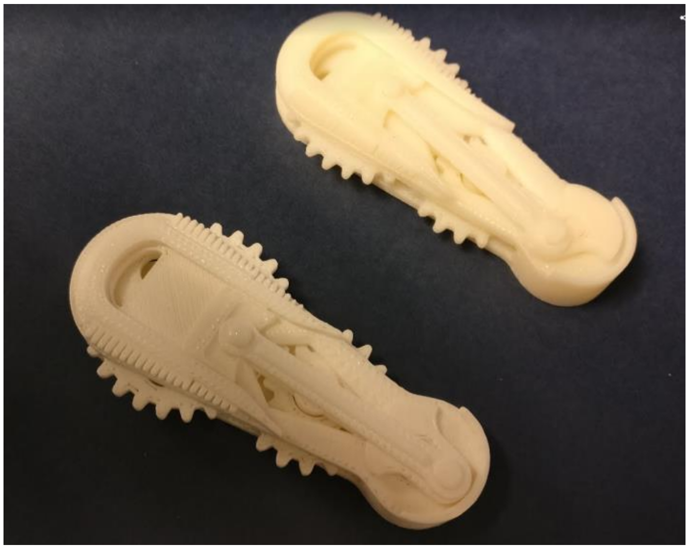

Representative part made by 3D printing or additive manufacturing

<u>Follow up questions of the Case</u>
After presenting the case to the students, the questions to students are:

1. How could the model employed here be used at a community level and what might that look like? What challenges would one face?

2. Could a similar model to this be used at Tech Square and other start up incubation areas? What challenges would one face?

3. What could Ga Tech do to further enhance the experience and use of this center by students?

SLS ESSC Blog Post

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The SLS *Energy Systems for Sustainable Communities* Fellows Program provided an excellent platform for thinking about and discussing the concept of sustainability—both as applied to energy systems and more generally—with GT colleagues and students. The diverse background of program participants ensured that a variety of perspectives were brought to bear on the subject. The guest speakers and program activities were informative and enjoyable. I am glad to have had this opportunity to get involved with SLS, and look forward to potential collaborations with colleagues I may not have been connected with otherwise. Below, I have provided a short reflection on the program's core topic:

How do economists think about "sustainability", as regards energy systems or any type of socio-economic system? Generally speaking, sustainability requires that the needs of the current generation be met without sacrificing the well being of future generations. Economists therefore consider sustainability as satisfying two fundamental conditions: *dynamic efficiency* and *intergenerational equity*.

Dynamic efficiency implies that at every point in time, the existing generation maximizes the net benefits of it economic system. However, a crucial component to this is that *all* relevant benefits and costs—including those accruing to future generations as a result of current production and consumption decisions—are properly accounted for. One example of such future benefits and costs, referred to as "externalities" because the future generations to whom they accrue are *external* parties to the economic decisions that generated them, include the benefits of transitioning our energy systems away from carbon-intensive fuels or, conversely, the costs of not doing so.

If dynamic efficiency is the *necessary* condition for ensuring sustainability, intergenerational equity is the *sufficient* condition. Intergenerational equity means simply that the maximized net benefits to society are non-decreasing over time. In other words, we must ensure that future generations are at least as well-off as we are today. If meeting our energy needs today by burning fossil fuels implies that future generations will be less well-off due to the wide-ranging negative consequences of increased stocks of atmospheric CO_2, the condition of intergenerational equity will be violated and sustainability will not have been achieved.

For these two conditions to be met, it will take a concerted effort by individuals, firms, educators, non-profit organizations, and governments, at all levels of community—from the household to the neighborhood to the city to the nation, all the way up to the global community—to continue to raise awareness, alter behavior, and bring about lasting change. Sustainability is both an ideal to strive toward globally and a reality that can be achieved locally. The GT-SLS initiative is certainly doing its part, and serves as a torch-bearer to help light the way to a more sustainable future.

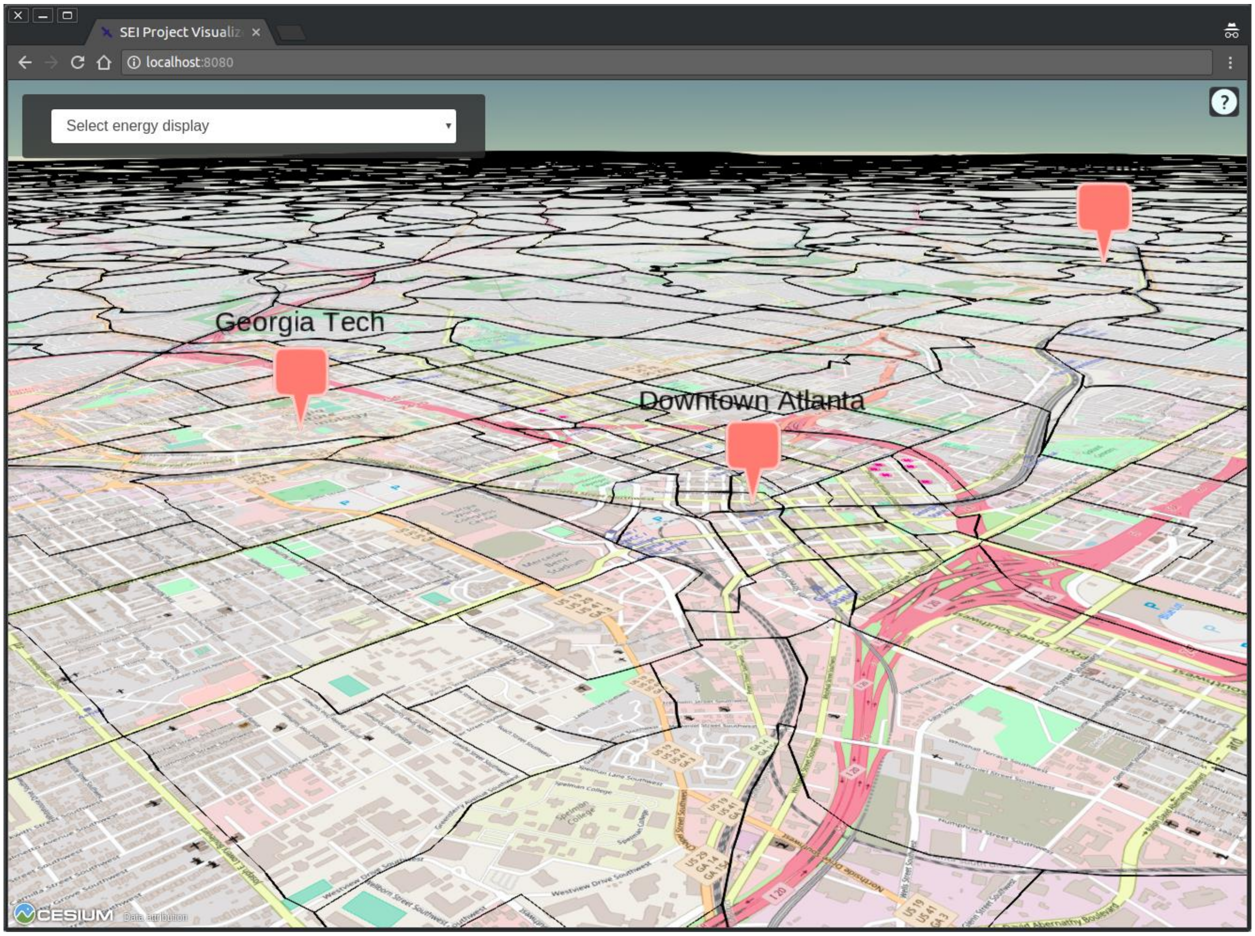
Visualizing Energy Consumption

Caleb Robinson, PhD Candidate
School of Computational Science and Engineering

I am a Ph.D. student in the School of Computational Science and Engineering and much of my research is in the field of Computational Sustainability. Computational Sustainability involves using computational methods and techniques to help answer questions related to sustainability in broader application domains, which makes collaborating and learning from people outside of the traditional boundaries of computer science a key point of much of my work. The Serve Learn Sustain (SLS) program promoted exactly this type of interdisciplinary collaboration over the past semester and was an excellent experience overall.

One of the things that I learned over the semester in the SLS program was how important communication is in sustainability research. Every discipline comes with its own language, how computer scientists "speak" is different from how chemists "speak" which are both different from how mechanical engineers "speak". Every step in the research process, from identifying a common problem that a group of *interdisciplinary* researchers can work on together, to the nittygritty details of the work itself, to the final result, will all require communication efforts that are different, and more difficult, from the more traditional, *intradisciplinary* research in one's own field. While difficult, these communication efforts can be very rewarding. Throughout the semester I learned about a broad spectrum of fascinating sustainability research that touched on subjects like: how people interact with buildings, how communities can get more value out of solar power, and how microgrids can fit in with local economies.

During the semester, all of the SLS fellows went on a campus sustainability tour that included a demo of a Virtual Reality crowdsourcing application for the Georgia Tech Living Building. This application is a great example of a method for communicating with and getting feedback from cross-disciplinary stakeholders (and is indeed the purpose of the Living Building project). This application inspired me to create a visualization tool to communicate my own research about building energy consumption in an accessible way. As part of a project with the Summer Engineering Institute (SEI) at Georgia Tech, my collaborators and I have created methods for estimating the residential, commercial, and transportation energy consumption of Traffic Analysis Zones (TAZ) in the 20 county Atlanta metropolitan area. To demo the results of this research I have created an interactive web based visualization application that shows the consumption levels of each TAZ and allows the user to explore this energy consumption landscape in 3D. Figure 1 shows a screenshot of the application without any data loaded onto it, i.e. a 3D view of Atlanta, Figure 2 shows the same view from the application where the per-TAZ residential energy consumption values have been loaded, and finally Figure 3 shows the same view where all three energy consumption categories are shown. This application will be useful in demonstrating *what* our methods are capable of estimating, and further, *what we can learn* from these estimates. Moving forward in my Ph.D., I hope to apply the things that I have learned in the SLS program and focus on using effective communication to better achieve sustainability goals.


SEI Project Visualiz
localhost:8080
Select energy display
Georgia Tech
Downtown Atlanta
CESIUM
Figure 1.

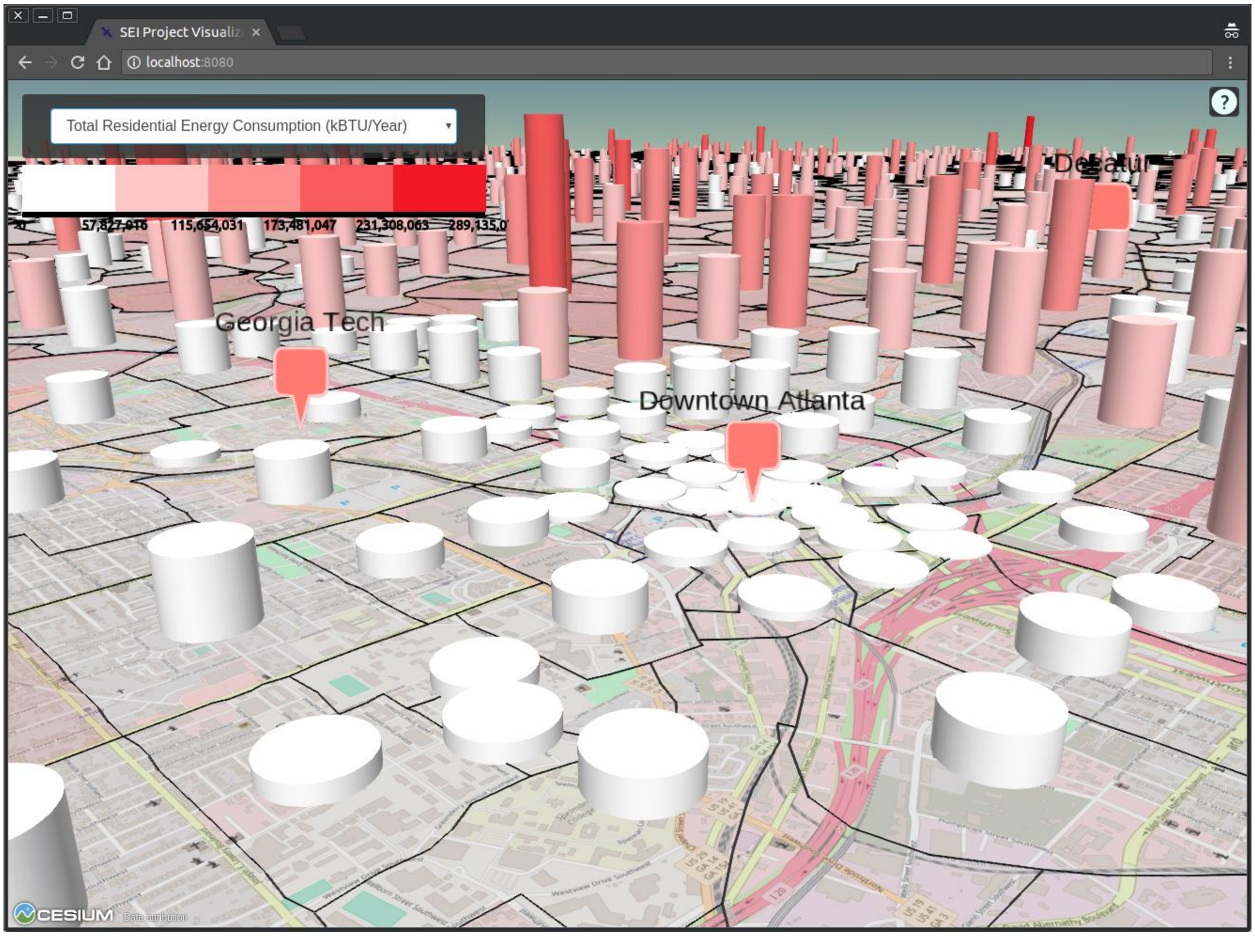

SEI Project Visualiz
localhost:8080
Total Residential Energy Consumption (kBTU/Year)
0
57,827,016
115,654,031
173,481,047
231,308,063
289,135,0
Georgia Tech
Downtown Atlanta
Decatur
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Figure 2.

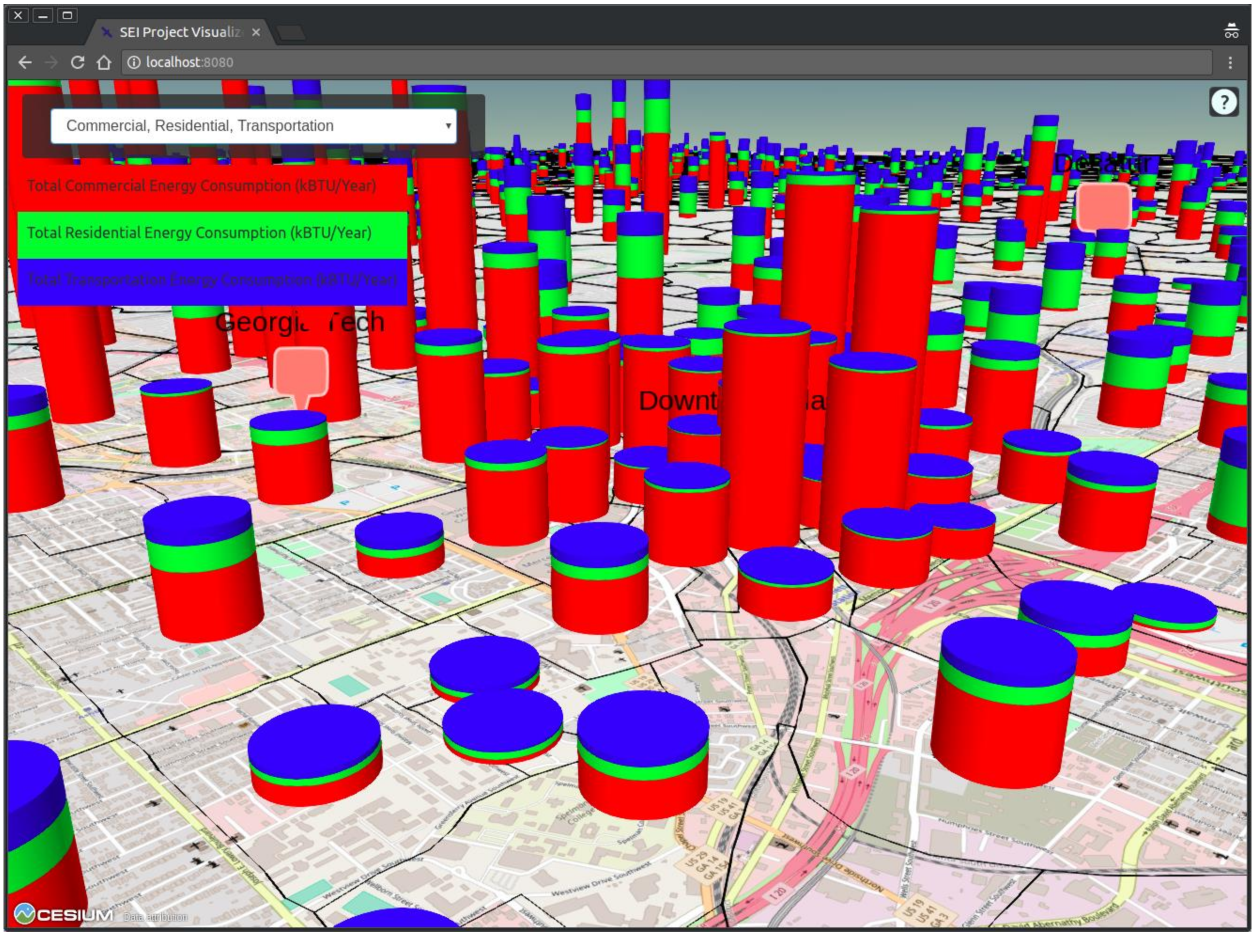

Figure 3.

SLS ESSC Blog Post

Greg Spiro, Senior Mechanical Engineer
Facility Design and Construction

My name is Greg Spiro and I am a Mechanical Engineer in Facilities Design and Construction. Unlike others in the SLS Fellows program, I do not conduct my own research or teach students. I do work with researchers on campus to promote the campus as a Living Learning Laboratory in conjunction with the projects we deliver. I am very passionate about sustainability in general and always interested in learning about others' initiatives. In my personal life I engage in sustainable practices including recycling, composting, purchasing vegetables from a CSA, rainwater harvesting, driving an electric vehicle and carpooling. My focus at work is on water and energy in the built environment and promoting our campus sustainability initiatives. I find this work to be rewarding as buildings make up roughly 40% of US energy use (transportation and industry splitting the remainder) and city of water costs are some of the highest in the country.

At the first SLS fellows meeting I was inspired by Jenny Hirsh's discussion and focus on equity as it relates to the Living Building project. In my own engagement on the project, I found this area of focus to be the least well defined of the petals i.e.: Place, Water, Energy, Health & Happiness, Materials, Beauty and Equity. I had been developing ideas of how stories related to specific sites on campus, in particular around the Living Building site, could well tie into the restorative nature of the work around the Living Building and Eco-Commons site. In discussions with team leaders, the idea was always well received but no one seemed ready or willing to champion the telling. I shared these thoughts with Jenny after the meeting as I felt she could potentially be such a champion and this became the focus of my Fellows work. Below is an excerpt from follow up correspondence to give a sense of the stories I hope are developed:

> The site of the Living Building @ Georgia Tech is adjacent to the old Neely Nuclear facility that was recently decommissioned. The site is now phase I of the campus eco-commons. The eco-commons itself is an expression of the past in that it looks to speak to the natural storm water pathways that existed before underground pipe was installed to convey stormwater. Water being a cleansing force, I think there's a good story line here. If we actually build out the blackwater facility (similar to Emory's Waterhub), even more so. The site is also very close to the old Pickrick Restaurant which too has been demolished. There is a plaque at the site commemorate it. This site also represents a place in need of cleansing but unique in it being a battleground fought and won by those against segregation so it's also worth celebrating. In that same vein, our campus and city represent a place vital to the civil war. I think there are also stories unique to our campus that can speak to a maturing viewpoint of equality. We are today a school that embraces a wide array of cultures but began as a school open to men only. One story that I heard a few years ago but never before as an alumni was that told by Gerald Ford's biographer. Apparently Ford played football for Michigan and was much impacted by Georgia Tech's refusal to play his team in 1934 if they allowed Willis Ward, a black player, to participate. Below are a couple of articles I found that details this event. Ward himself was an interesting figure. I've also linked a couple of things I found on the Pickrick.
>
> Gerald Ford stood up for teammate against racist policy:
> http://www.mlive.com/wolverines/index.ssf/2011/02/future_president_gerald_r_ford.html
>
> https://www.michigandaily.com/sports/forgotten-man-remembering-michigan-trailblazer-willis-ward-day
>
> Lester Maddox and the Pickrick:
> http://www.civilrights.uga.edu/cities/atlanta/atlanta_printable/pickrick_cafe_printable.html
> http://atlantatimemachine.com/misc/pickrick.htm

This semester I have met with Ruth Yow and others on campus interested in developing classwork around this idea of documenting campus historical stories. I understand there may be multiple opportunities to document such stories through coursework. I look forward to hearing and learning from these stories and hope to be able to weave them into the project work that is ongoing on the very sites that hold their history.

Can History and other Humanities and Social Sciences Contribute to A Better Understanding of Energy Systems?

Germán Vergara, Assistant Professor
School of History and Sociology

This blog offers a brief (and non-comprehensive) overview of the humanities scholarship on energy. The purpose of the blog is to briefly introduce scholars from non-social science disciplines and fields into what may loosely be termed "energy humanities," which include history, sociology, anthropology, literature, and philosophy, among other disciplines. I focus on my own field of history, but also provide references to works in other disciplines for those readers who might want to delve deeper into this literature. I also offer a few words on social science energy research, traditionally dominated by economics and political science. My hope is that the blog will spur some SLS fellows to take the plunge and explore for themselves this large and growing body of research.[1]

A burgeoning social science literature now exists on energy, most of it published within the last two decades.[2] This scholarship is diverse in terms of topics, methodologies, and scope, but some trends can be identified. Probably the most recurrent topic is energy transitions (often defined as the shift of an economic system from one predominant source of energy to another), in particular the political and economic conditions that make them possible or that accelerate or slow them down. In general, this research tends to concern itself with how energy systems and transitions are embedded in political, social, economic, and institutional contexts. Other salient topics include energy governance, energy justice and poverty, and the social dimensions of energy technologies. There is a strong inclination towards quantitative analysis, although ethnographic and qualitative studies are not uncommon, and much of this work evinces a desire to produce results that can shape policy making. Since 2014, the journal *Energy Research & Social Science* has become a leading publication in the field under the direction of Arhus and Sussex University energy scholar Benjamin Sovacool.

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[1] Scholars in outside fields seldom consult social science and humanities scholarship on energy. See Benjami Sovacool, "What Are We Doing Here? Analyzing Fifteen Years of Energy Scholarship and Proposing a Social Science Research Agenda," *Energy Research & Social Science* 1 (2014): 1–29. This suggests that C.P. Snow's concept of the "two cultures" dividing the "hard" sciences from the social sciences and humanities is as relevant today as when he formulated it in 1959. See C. P. Snow and Stefan, *The Two Cultures* (London ; New York: Cambridge University Press, 1993).

[2] Good overviews of this body of work are Kathleen Araújo, "The Emerging Field of Energy Transitions: Progress, Challenges, and Opportunities," *Energy Research & Social Science*, 2014, 112–21; Arnulf Grubler, "Energy Transitions Research: Insights and Cautionary Tales," *Energy Policy* 50 (2012): 8–16; Daniel Spreng, "Transdisciplinary Energy Research-Reflecting the Context," *Energy Research & Social Science* 1 (2014): 65–73; Sovacool, "What Are We Doing Here? Analyzing Fifteen Years of Energy Scholarship and Proposing a Social Science Research Agenda."

A related, but historically-minded type of research also deals with energy transitions, concentrating on the economics of energy transitions and the relationship between energy consumption and economic growth over the past two centuries.[3] Such focus has allowed, for instance, the development of sophisticated quantitative historical series on energy production and consumption for individual countries and regions, above all Western Europe. A prominent example of this work is *Power to the People: Energy in Europe Over the Last Five Centuries*, by economic historians Astrid Kander and Paolo Malamina and environmental historian Paul Warde. *Power to the People* shows how the modern world owes much of its creation and development to the revolutionary energy transition to fossil fuels (first coal and then oil and natural gas) that began over two hundred years ago in Britain and has since spread worldwide. Modern global economic, population, and urban growth—these authors claim—would have been impossible without it.[4]

Although innovative and often of excellent quality, a common criticism of this quantitative and economics-centered approach is that it has been less effective in explaining the role of human agency in energy transitions. There is a tendency to portray such shifts in a somewhat mechanical and deterministic manner with little attention paid to historical contingency. But as

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[3] Robert C. Allen, "Backward into the Future: The Shift to Coal and Implications for the Next Energy Transition," *Energy Policy* 50 (2012): 17–23; Carlo Bardini, "Without Coal in the Age of Steam: A Factor-Endowment Explanation of the Industrial Lag Before World War I," *The Journal of Economic History* 57, no. 3 (September 1997): 633–53; Mauricio Folchi and Mar Rubio, "El consumo de energía fósil y la especificidad de la transición energética en América Latina, 1900-1930" (III Simposio Latinoamericano y Caribeño de Historia Ambiental, Carmona, 2006); Roger Fouquet, "The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service," *Energy Policy* 38 (2010): 6586–96; Maria Froeling, "Energy Use, Population and Growth, 1800-1970," *Journal of Popular Economics* 24 (2011): 1133–63; Ben Gales et al., "North versus South: Energy Transition and Energy Intensity in Europe over 200 Years," *European Review of Economic History* II (2007): 219–53; Iñaki Iriarte-Goñi and María-Isabel Ayuda, "Not Only Subterranean Forests: Wood Consumption and Economic Development in Britain (1850-1938)," *Ecological Economics* 77, no. 77 (2012): 176–84; José Jofré González, "Patrones de consumo aparente de energías modernas en América Latina, 1890-2003" (PhD diss, Universitat de Barcelona, 2012); Astrid Kander, "Economic Growth and the Transition from Traditional to Modern Energy in Sweden," *CAMA Working Paper*, no. 65 (September 2013): 1–35; Nuno Luis Madureira, "The Iron Industry Energy Transition," *Energy Policy* 50 (2012): 24–34; Paolo Malanima, "Energy Crisis and Growth, 1650-1850: The European Deviation in a Comparative Perspective," *Journal of Global History* 1 (2006): 101–21; Paolo Malanima, "Energy in History," in *The Basic Environmental History*, eds. Mauro Agnoletti and Simonee Neri Serneri (New York: Springer, 2014); Mar Rubio and Mauricio Folchi, "Will Small Energy Consumers Be Faster in Transition? Evidence from the Early Shift from Coal to Oil in Latin America," n.d.; Mar Rubio, "Energía, economía y CO2: España, 1850-2000," *Cuadernos Económicos*, no. 70 (n.d): 52–75; Mar Rubio, César Yáñez, Mauricio Fochil, and Albert Carreras, "Energy as an Indicator of Modernization in Latin America, 1890–1925.," *Economic History Review* 63, no. 3 (2010); David Stern and Astrid Kander, "The Role of Energy in the Industrial Revolution and Modern Economic Growth," (CAMA Working Papers Series 1/2011, November 1 2010); Paul Warde, *Energy Consumption in England & Wales, 1560-2000* (Roma: Consiglio nazionale delle ricerche, Istituto di studi sulle società del Mediterraneo, 2007). Worth mentioning for its breadth as well as for its tendency towards technological determinism is the pioneering work of Vaclav Smil. See Vaclav Smil, *Energy in World History,* Essays in World History (Boulder: Westview Press, 1994); Vaclav Smil, *Energy in Nature and Society: General Energetics of Complex Systems* (Cambridge: MIT Press, 2008); Vaclav Smil, *Energy Transitions: History, Requirements, Prospects* (Santa Barbara: Praeger, 2010).

[4] Astrid Kander, Paolo Malanima, and Paul Warde, *Power to the People: Energy in Europe over the Last Five Centuries,* (Princeton: Princeton University Press, 2015).

the work of other energy scholars suggests (see below), the views and motivations of historical actors and social and political relationships have profoundly shaped the timing and trajectory of energy shifts. This body of work also tends to overlook the environmental context and impact of adopting new energy sources.

Perhaps as a response to these shortcomings, the new field of energy humanities has placed both the social and environmental aspects of energy systems at the center of its research agenda. Perhaps the best introduction, as well as the most indicative of the state of the field, is the recent volume *Energy Humanities: An Anthology*,[5] edited by Dominic Boyer and Imre Szeman. These scholars agree with authors such as Kander, Malanima, and Warde that the emergence of modern, industrial civilization cannot be understood without taking into account the global transition to fossil fuels. Boyer and Szeman also emphasize that key elements of modern societies, from increasing urbanization to economic growth and the massive expansion of global trade have been enabled by an equally massive influx of cheap energy from fossil fuels. Scholars in the energy humanities, however, are much more attentive to the capacity of energy regimes to mold human social relations and cultural practices and to how these, in turn, shape energy use. A common thread in energy humanities is a critique of energy research that narrowly privileges technical aspects, ignoring the crucial role of social structures and cultural practices in shaping energy systems. As Boyer and Szeman contend, "our energy and environmental dilemmas are fundamentally problems of ethics, habits, values, institutions, beliefs, and power—all areas of expertise of the humanities and humanistic social sciences."[6]

Another characteristic that defines energy humanities scholars—and clearly separates their work from non-humanistic and, to some extent, social science energy research—is their tendency to call into question the foundations of modern energy systems. These scholars point out that the fossil-fueled growth upon which modern industrial societies depend (both capitalist and socialist), is unsustainable and inequitable. Taking a cue from ecological economists, energy humanists criticize the "growth dogma" and the desirability and possibility of endless growth on a finite planet. Skeptical of techno-optimist claims that technological innovation will solve most environmental problems caused by a fossil-fueled global economy such as global warming and ocean acidification, energy humanists also challenge market-based solutions to energy problems. This literature is often agnostic of the possibility for building "green capitalism," sustainable development (considered more or less an oxymoron) or a truly sustainable industrial society based on renewable sources of energy given that fossil fuels and industrial civilization have historically been inextricably intertwined. Many of these authors discuss the possibility that industrial capitalism as we know it might not survive a transition to a post-carbon world.[7]

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[5] Dominic Boyer and Imre Szeman, eds., *Energy Humanities: An Anthology* (Baltimore: Johns Hopkins University Press, 2017).

[6] See Dominic Boyer and Imre Szeman, "Breaking the Impasse: The Rise of Energy Humanities," University Affairs, 42, March 2014, http://www.universityaffairs digital.com/universityaffairs/201403?pg=42&lm=1480552083000.

[7] See "Introduction: On the Energy Humanities," in Boyer and Szeman, *Energy Humanities*.

Environmental historians, who look at the reciprocating relationship between human societies and the environment in the past, have pursued similar aims to scrutinize the influences between the environment, industrial civilization, and energy systems and transitions. [8] There is an effort to understand not only how different types of energy sources have had social and environmental effects, but, as with energy humanities, how certain environmental conditions and social and cultural practices have shaped energy systems and transitions. Energy has become one of the key conceptual tools in environmental history. In fact, energy is often central in how practitioners in the field narrate the past. Environmental history periodizations (that is, the way in which historians parcel out the past into discreet chunks of time) are often organized around energy regimes and transitions.[9] For instance, leading environmental historian John R. McNeill showed in his classic account *Something New Under the Sun: An Environmental History of the Twentieth-Century World* that exponential increase in energy use was one of the trademarks of the unprecedented changes that characterized the twentieth century.[10] He followed fifteen years later with *The Great Acceleration: An Environmental History of the Anthropocene*, a study of the world since 1945 that highlights the role of energy systems and use in the emergence of the Anthropocene, a new geological period in which humans have become one of the most powerful forces shaping the biogeochemistry of the planet.[11]

Between the publication of McNeill's books in 2000 and 2016, a profusion of books and articles on energy history that tackle a wide variety of topics have been published.[12] To mention but a

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[8] See Rolf Peter Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: The White Horse Press, 2001). See also Stefania Barca, "Energy, Property, and the Industrial Revolution Narrative," *Ecological Economics* 13, no. 1 (February 2007); Fridolin Krausmann, "Land Use and Industrial Modernization: An Empirical Analysis of Human Influence on the Functioning of Ecosystems in Austria, 1830-1995," *Land Use Policy* 18 (2001): 17–26; Fridolin Krausmann, "Land Use and Socio-Economic Metabolism in Pre-Industrial Agricultural Systems: Four Nineteenth-Century Austrian Villages in Comparison," *Social Ecology* Working Paper, no. 72 (December 2008): 1–40; Martin V. Melosi, "Energy and Environment in the United States: The Era of Fossil Fuels," *Environmental Review* 11, no. 3 (Autumn 1987): 167–88; "A Landscape of Energy Abundance: Anthracite Coal Canals and the Roots of American Fossil Fuel Dependence, 1820-1860," *Environmental History* 15 (July 2010): 449–84.

[9] Edmund Burke III, "The Big Story: Human History, Energy Regimes, and the Environment," in *The Environment and World History* (Berkeley: University of California Press, 2009), 33–53.

[10] John Robert McNeill, *Something New under the Sun: An Environmental History of the Twentieth-Century World* (New York: W.W. Norton & Company, 2001).

[11] J. R. McNeill and Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge: Massachusetts: Belknap Press: An Imprint of Harvard University Press, 2016).

[12] Although not strictly speaking a history of energy, no overview of energy research, however brief, can fail to mention political scientist Timothy Mitchell's influential and historically-minded *Carbon Democracy: Political Power in the Age of Oil* (London; New York: Verso, 2011). Mitchell argues that energy sources profoundly shape political systems and seeks to demonstrate a close connection between the material properties of coal and oil and politics. While coal strengthened working class political agency and created the preconditions to widespread democratization, oil's supply networks and properties as a fluid made it less vulnerable to workers' political claims. As is the case with energy humanists, Mitchell seems agnostic of the long-term viability of an economic system predicated on endless fossil-fueled growth.

few prominent examples, the *Journal of American History* published in 2012 a special edition devoted to the role of oil in U.S. history, exploring oil history from diverse angles such as religion, environmental effects, urbanization, popular culture, and foreign policy, among others.[13] Barbara Freese's *Coal: A Human History*, emphasizes the dual role that coal has played since the Industrial Revolution as both a blessing that enabled modern prosperity and a curse upon the global environment and human health.[14] Martin Melosi explores the energy history of cities in *Energy Capitals: Local Impact, Global Influence* and *Energy Metropolis: An Environmental History of Houston and the Gulf Coast*.[15] The first book examines from a comparative perspective the diverse and often contradictory political, economic, and environmental effects that fossil energy production has had on cities around the world, from Canada, the US, and Mexico to Africa and Australia. The second book is a collection of essays that focuses on how Houston's political and economic elites promoted the exploitation of the enormous fossil bounty in their area, often at the expense of the city's poor inhabitants and the region's environment. More recently, Christopher Jones has highlighted the importance of studying the social history of energy infrastructure to better understand energy transitions in *Routes of Power: Energy and Modern America*.[16]

Energy has begun influencing the work of other historians, too. Cultural historians, for example, until recently reluctant to engage with the material underpinnings of cultural practices, seem to be finally catching up and are increasingly paying attention to energy, especially fossil fuels. We now have books on "energy cultures" that, among other things, examine the role of oil as a cultural object, cultural representations of energy, and the myriad ways in which energy systems shape and "fuel" cultural production. In *Living Oil: Petroleum Culture in the American Century*, ecocritic Stephanie LeMenager engages with the aesthetic and ecological legacies of oil in U.S. twentieth-century cultural artifacts, including photography, novels, Hollywood films, museums, and even hamburgers to illustrate the "oil-saturated" nature of American petroculture.[17] Along similar lines, the collective volume *Oil Culture* analyzes the nexus between oil and culture ("petroaesthetics") in film, museums, and technologies such as cars, to illustrate oil's ubiquity in American capitalism.[18]

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[13] "Oil in American History," *Journal of American History* 99, no. 1 (June 2012), http://archive.oah.org/issues/issues/991/index.html.

[14] Barbara Freese, *Coal: A Human History* (Cambridge, MA: Perseus Pub., 2003).

[15] Martin V Melosi and Joseph A Pratt, *Energy Metropolis: An Environmental History of Houston and the Gulf Coast* (Pittsburgh: University of Pittsburgh Press, 2007); Joseph A. Pratt, Martin V. Melosi, and Kathleen A. Brosnan, eds., *Energy Capitals: Local Impact, Global Influence*, 1 edition (Pittsburgh: University of Pittsburgh Press, 2014).

[16] Christopher F. Jones, *Routes of Power: Energy and Modern America*, 2014.

[17] Stephanie LeMenager, *Living Oil: Petroleum Culture in the American Century*, Oxford: (Oxford University Press, 2016).

[18] Ross Barrett and Daniel Worden, eds., *Oil Culture* (Minneapolis: University Of Minnesota Press, 2014). Other relevant titles are Bob Johnson, *Carbon Nation: Fossil Fuels in the Making of American Culture* (Lawrence:

Historian Christopher Jones argues that history can contribute to energy research and energy policy makers by bringing attention to overlooked features of energy systems, in particular the essential connections between culture, society, and energy.[19] Most of the historians and scholars overviewed in this blog—along with this writer—would certainly agree with him. But more than simply highlighting the connections between energy systems and their social and historical contexts, energy history and humanities offer tools for examining them *critically*. Underscoring the unprecedented nature of fossil-fueled industrial civilization, with its explosive rates of economic, urban, and population growth, this scholarship invites non-humanities scholars to engage more fully and critically with the bigger questions: Is continual economic growth sustainable on a finite planet? Can there be a truly sustainable industrial society? Can industrial civilization survive a transition to a post-carbon world? The answers to these questions hold untold potential for shaping the future of the world; energy history and humanities seek those answers.

SLS ESSC Blog Post

Eunhwa Yang, Assistant Professor
School of Building Construction

I've started the SLS fellowship on Energy Systems for Sustainable Communities (ESSC) with a general goal of understanding local organizations that work on energy systems and expanding my network with GT scholars and professionals who have similar interests in sustainability. The ESSC fellows added much value by bringing their different research and teaching experiences, which reflected the SLS's approach on sustainable communities, addressing two or more aspects of sustainability: environment, society, and economy. Moreover, discussing the UN's sustainable development goals in the workshop provided me a great opportunity to think about broader impacts of my current research projects and shape my future research plan.

I'd like to share my reflection of being an SLS ESSE fellow by linking my current research projects. The first project is related to green leasing. Although the term "green leasing" is not yet well defined, its primary purpose is clear. With an aim to create a collaborative environment through legal provisions between a building owner and a tenant, green leasing may ultimately help resolve the energy paradox in tenanted properties. These issues surrounding split-incentive are driven by a mismatch between– owners' capital expenditures on improving building energy efficiency and an uncertainty of tenant or occupant behavior that might affect a building's energy consumption. Though some countries have started to develop guidelines promoting the adoption of green leasing, especially in government buildings and commercial real estate, implementation has not been overly successful globally. The project compares green leasing guidelines from various countries and suggests comprehensive categories of green leasing components: management relationships, information sharing, certificates, legal stipulations, financial factors,

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University Press of Kansas, 2014) and Imre Szeman, Jennifer Wenzel, and Patricia Yaeger, eds., *Fueling Culture: 101 Words for Energy and Environment* (New York: Fordham University, 2017).

[19] Richard Hirsh and Christopher F Jones, "History's Contributions to Energy Research and Policy," *Energy Research & Social Science* 1 (2014): 106–11.

and operation. Also, document analysis of previous lease agreements will provide evidence of green leasing in government-tenanted properties in the United States.

The second project is related to repurposing and repositioning of malls. Many malls in the United States go through different stages of a building life cycle as facilities age, e-commerce markets emerge, and local economies change. Approximately, 42 percent of malls in the U.S. suffer from losing their anchor tenants such as department stores and finding new retailers large enough that require such space as outdated facilities lose their fresh, modern look[20]. This is largely because many department stores including Sears, Macy's, and J.C. Penny have closed already or are at risk of closing their locations with the rise of e-commerce. According to the research from Green Street Advisor, as reported by The Wall Street Journal, department stores have to close approximately 800 store locations in order to achieve the same level of sales productivity in 2006[21]. The report also highlighted that 800 store locations were about one-fifth of all anchor space in the U.S. malls. Given statistics, many malls (will and must) undergo redevelopment. There are many factors to consider to repurpose/reposition a mall including financial, physical, legal, environmental, and societal aspects. Case studies in the metro Atlanta area will provide some insights on other malls in similar situations.

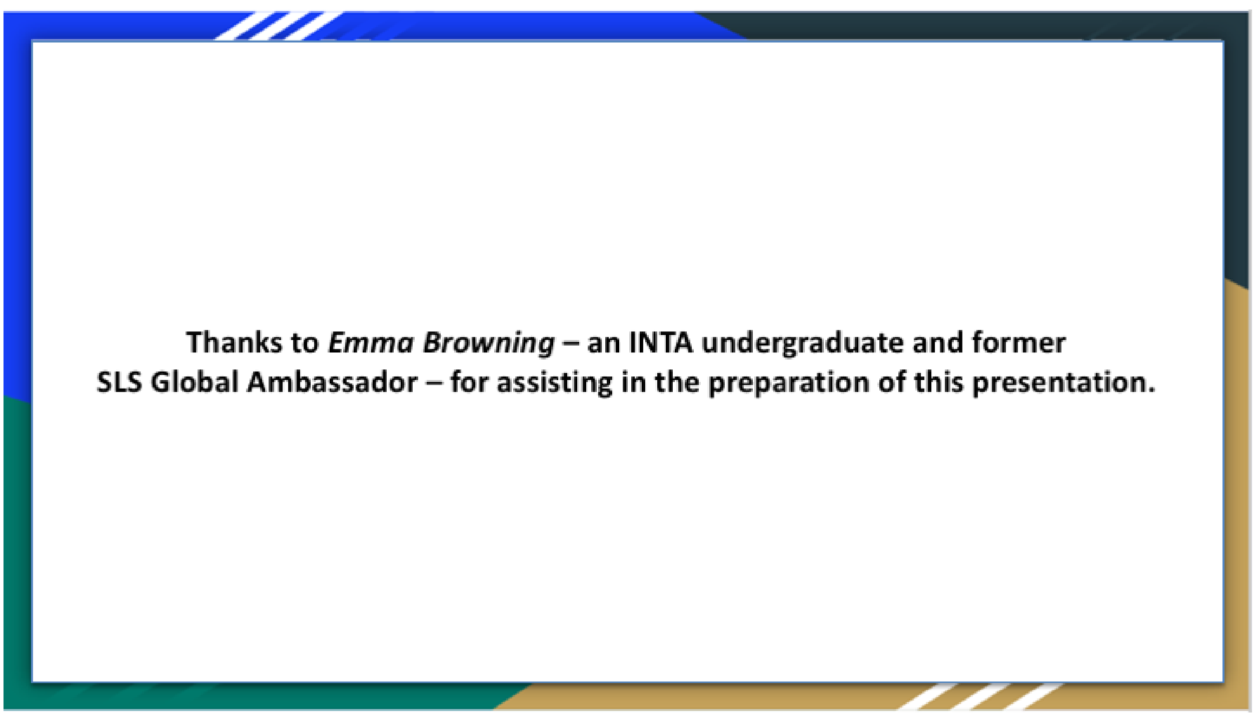
The SLS's ESSC fellowship provided me a chance to think through the broader impacts of my current research projects and motivated me to build a detailed future research plan that I hope to ultimately contribute to economic, environmental, and societal sustainability.

[20] Bonislawski, A. (2016). The second life of failed malls. Retrieved from https://commercialobserver.com/2016/06/the-second-life-of-failed-malls/

[21] Kapner, S. (2016). Department stores need to cull hundreds of sites, study says. The Wall Street Journal. Retrieved from https://www.wsj.com/articles/department-stores-need-to-cull-hundreds-of-sites-study-says-1461520952

Energy Security and Environmental Security: What Can Atlanta Learn From Tokyo

Brian Woodall, Professor
Sam Nunn School of International Affairs



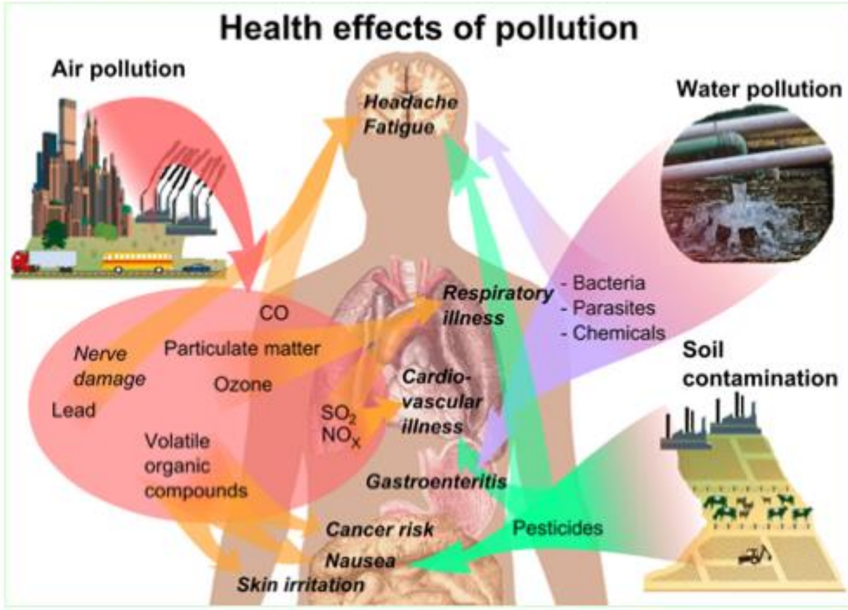
Presentation Outline

1. Energy security and environmental security – two sides of the same coin
2. Paired comparison – Atlanta and Tokyo
3. Energy supply and demand
4. Environmental challenges
5. Policy responses and risks
6. Findings
7. Issue for further research: is inclusive green growth possible?

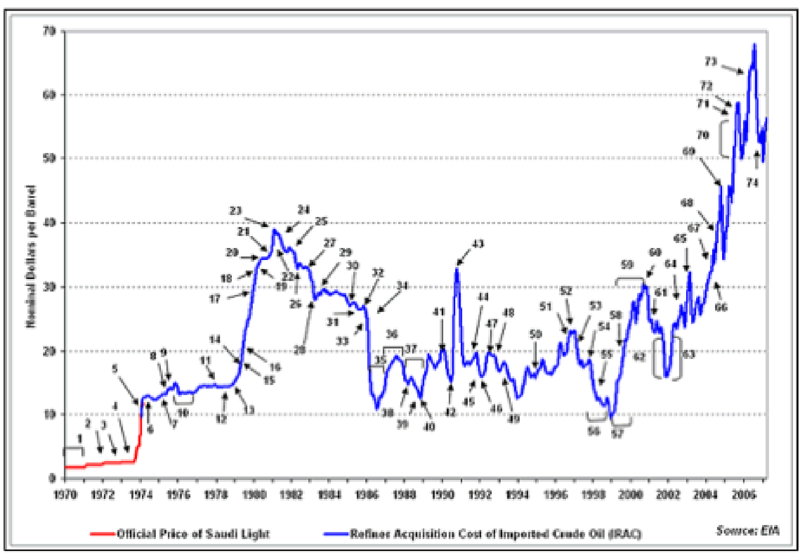
Energy-Smart City Concept (Agartala Municipal Corporation)

“We must treat energy security and climate security as two sides of the same coin”

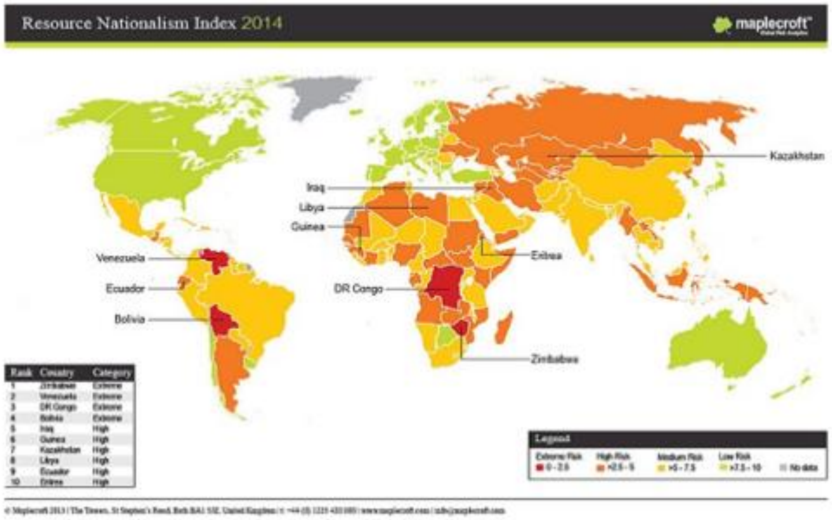
What are the ***costs*** of unsustainable energy choices?



Rising – often unpredictable – energy costs



Resource nationalism ⟶ conflict

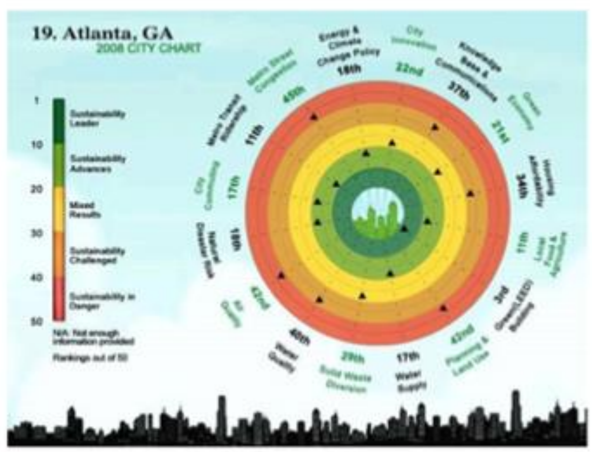


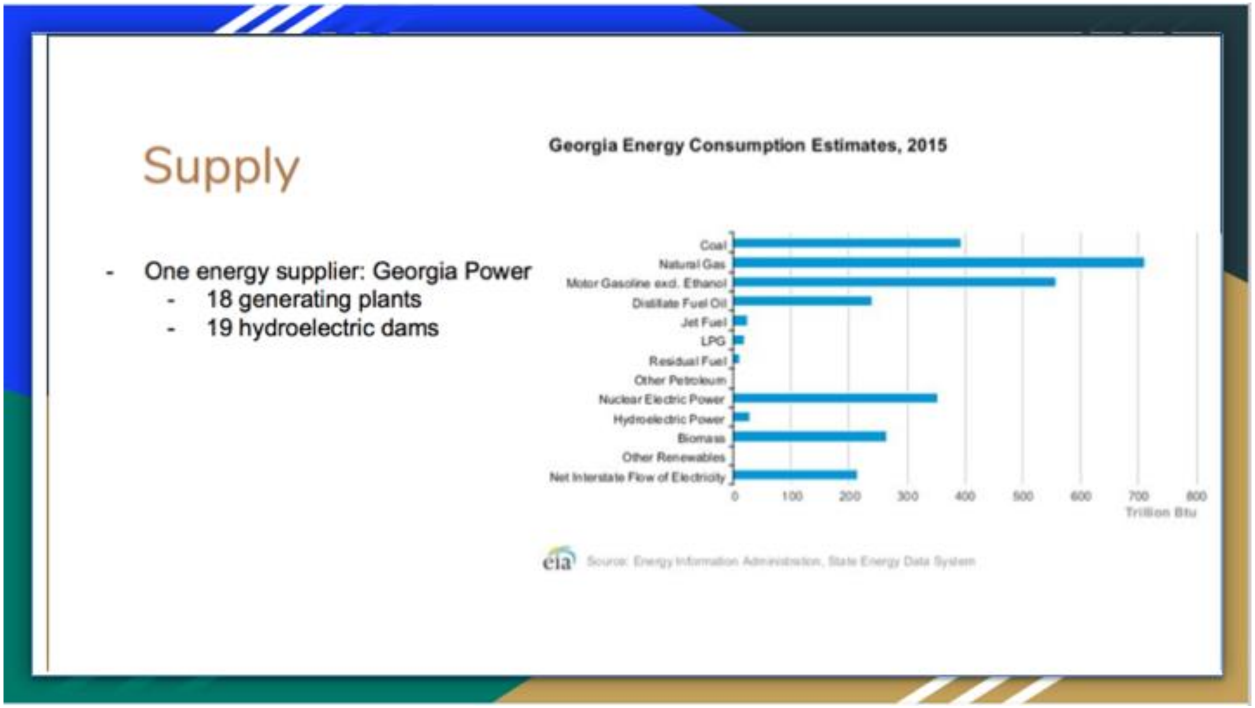
Social and political strife… ***<u>disadvantaged interests</u>*** seek redress

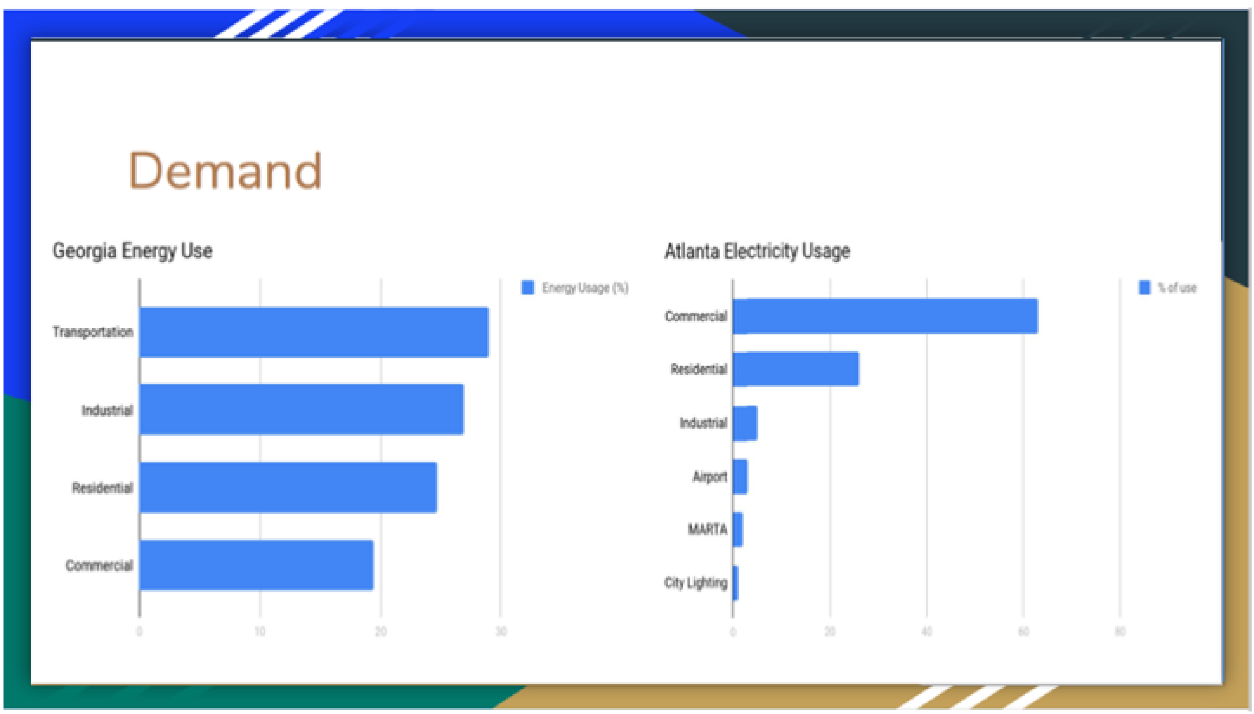
Energy security and environmental security in two cities – Atlanta and Tokyo

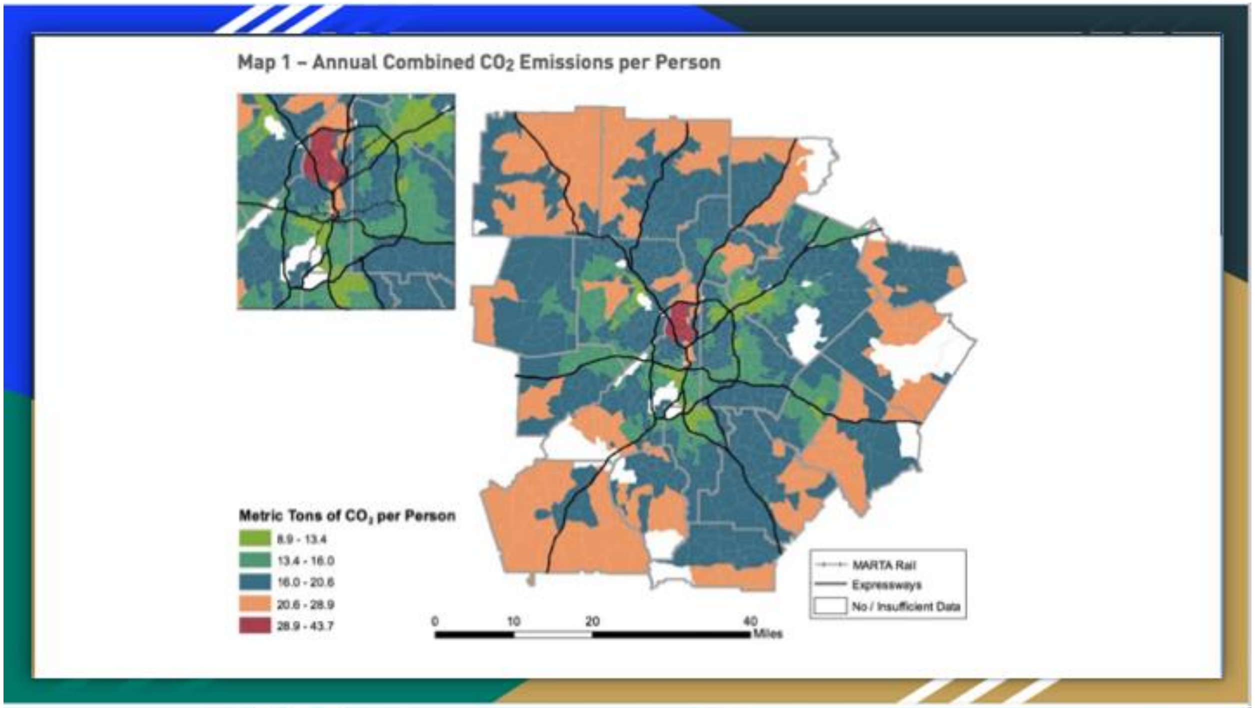
Atlanta

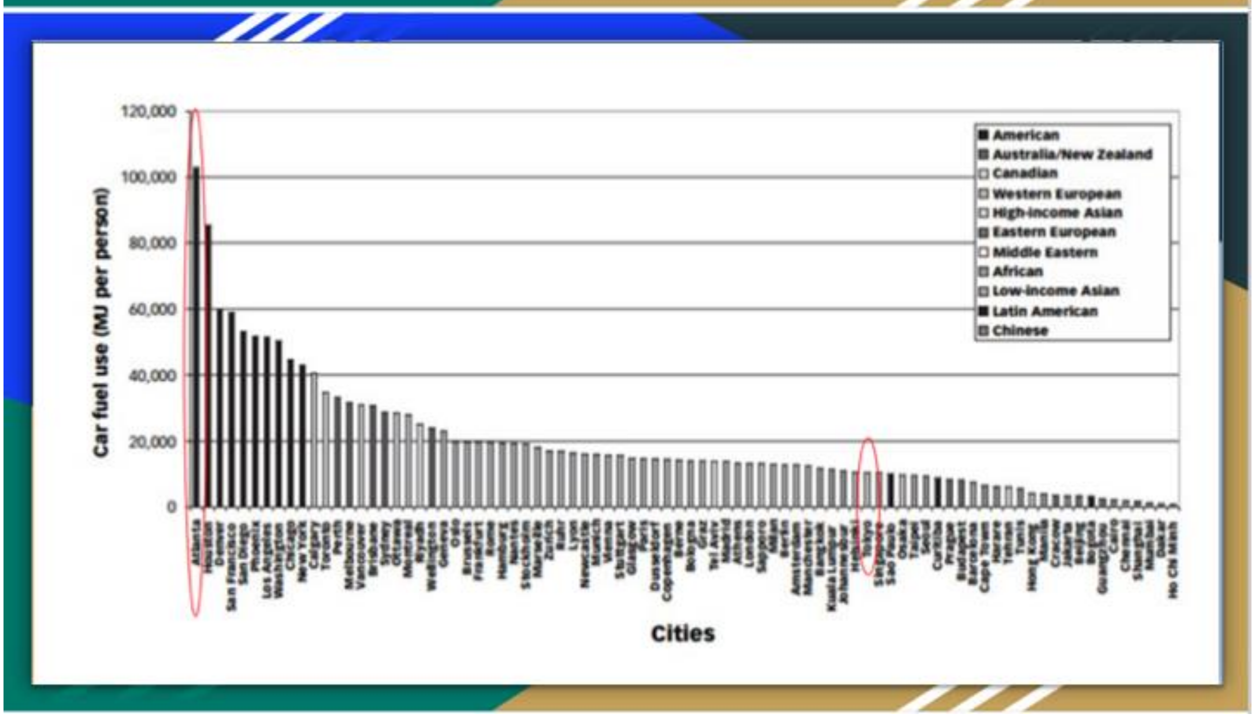
- 472,500 people (city)
    - 5.7 million people (metro)
- 134 square miles/347 square kms (city)
    - 8,376 square miles/21,690 square kms (metro)




Supply
- One energy supplier: Georgia Power
- 18 generating plants
- 19 hydroelectric dams
Georgia Energy Consumption Estimates, 2015
Coal
Natural Gas
Motor Gasoline excl. Ethanol
Distillate Fuel Oil
Jet Fuel
LPG
Residual Fuel
Other Petroleum
Nuclear Electric Power
Hydroelectric Power
Biomass
Other Renewables
Net Interstate Flow of Electricity
0 100 200 300 400 500 600 700 800
Trillion Btu
eia Source: Energy Information Administration, State Energy Data System

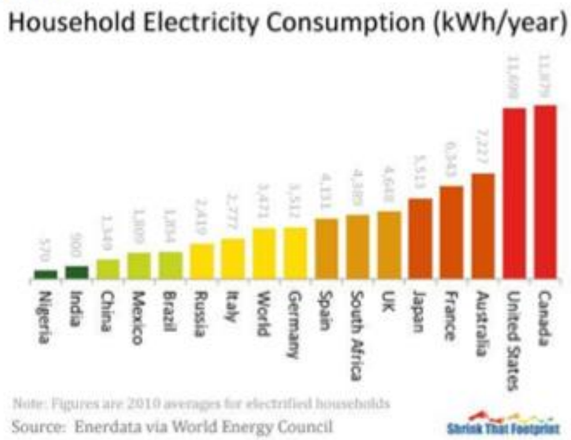

Demand
Georgia Energy Use
Energy Usage (%)
Transportation
Industrial
Residential
Commercial
0 10 20 30
Atlanta Electricity Usage
% of use
Commercial
Residential
Industrial
Airport
MARTA
City Lighting
0 20 40 60 80


Map 1 – Annual Combined CO_2 Emissions per Person
Metric Tons of CO_2 per Person
8.9 - 13.4
13.4 - 16.0
16.0 - 20.6
20.6 - 28.9
28.9 - 43.7
MARTA Rail
Expressways
No / Insufficient Data
0
10
20
40
Miles

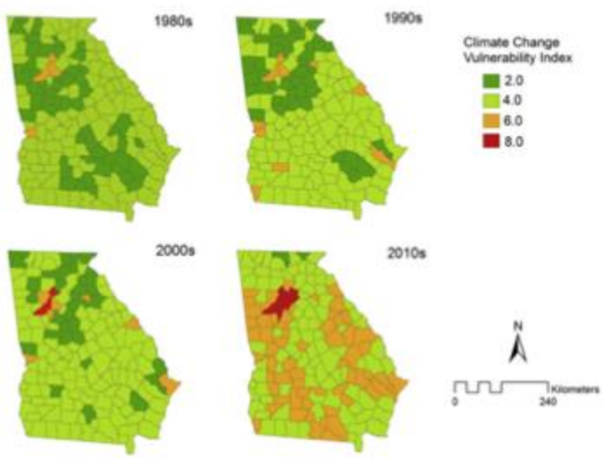

Car fuel use (MJ per person)
120,000
100,000
80,000
60,000
40,000
20,000
0
Cities
American
Australia/New Zealand
Canadian
Western European
High-income Asian
Eastern European
Middle Eastern
African
Low-income Asian
Latin American
Chinese

Demand Comparison

- Atlanta consumption is slightly below national average
- Tokyo consumption is approximately average



Atlanta: Security Risk

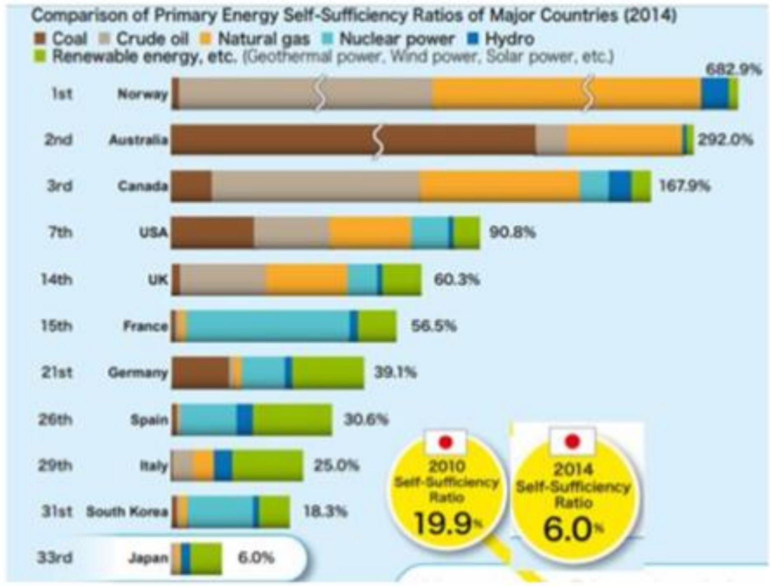


Steps Taken

Tokyo

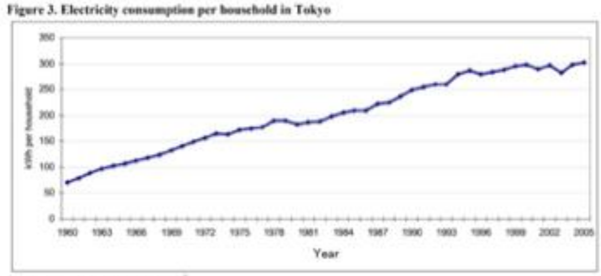
- 9.273 million people (city)
  - 38 million people (metro area)
- 844.66 square miles/2,187 square kms (city)
  - 5,240 square miles/13,572 square kms (metro area)

Supply



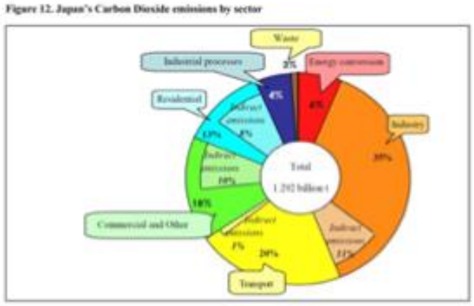
Demand

Figure 3. Electricity consumption per household in Tokyo



Source: TEPCO ILLUSTRATED 2008

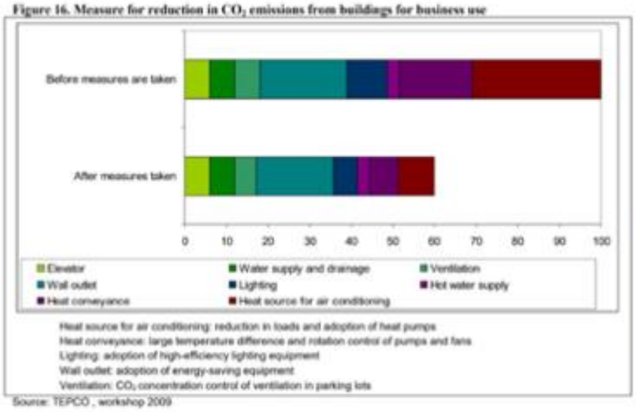
Figure 12. Japan's Carbon Dioxide emissions by sector



Source: Kyoto Protocol Achievement Plan (Revised March 2008), Ministry of Environment

Steps Taken

Figure 16. Measure for reduction in CO_2 emissions from buildings for business use



Source: TEPCO , workshop 2009

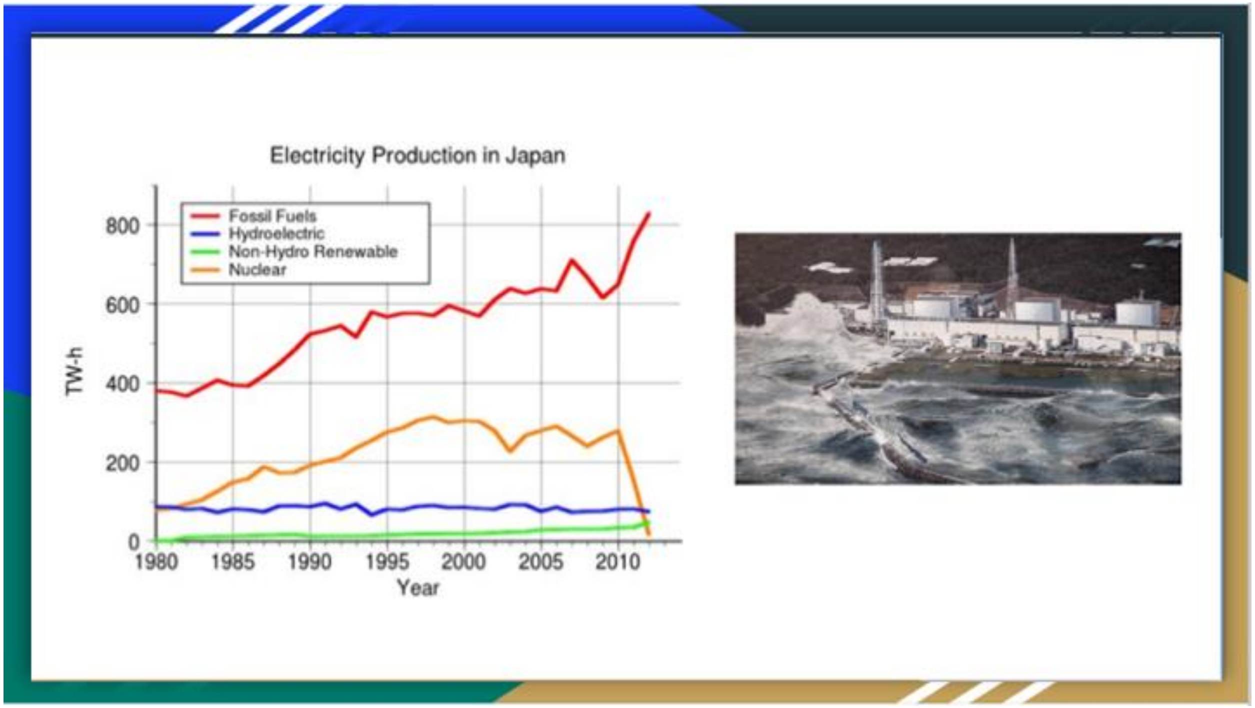
<u>What Can Atlanta Learn from Tokyo?</u>

- **Atlanta and Tokyo – two large cities, albeit of dramatically different scale – facing similar challenges regarding energy security and environmental security**
- **Atlanta could learn lessons from Tokyo – e.g., public transportation, city planning, inclusivity in infrastructure (e.g., energy infrastructure), long-range energy plan (focusing on renewables)**
- **Other lessons?**

Issue for further research:

Is *inclusive green growth* – the use of natural resources in a sustainable manner that assures that all residents share in the economic benefits – possible?


Tokyo: Security Risks
Ground motion probability map
(%)
26
6
3
0.1
0
High
Somewhat high
Distribution of probabilities that a quake of lower 6 or higher on the Japanese seismic intensity scale of 7 will occur over 30-year period from 2014. Based on documents of Headquarters for Earthquake Research Promotion



The Smart, Sustainable Neighborhood

Bob Myer, Professor
Scheller College of Business

It is a cold December 2017 day in Birmingham, AL. Tracy West has just arrived at her office and sits down. It almost seems foreign as all she has done lately is run from one meeting in one city to another. In fact, she has just returned from Washington DC providing testimony at some recent Senate hearings (Exhibit 1) about some of Southern Company's research and development (R&D) work on buildings-to-grid integration. While busy, it is an exciting time for her as the Director of End Use, Power Delivery and Fleet R&D at Southern Company. The Senate Energy and Natural Resources Committee was very interested to hear about the research her company is doing around microgrids and Smart Neighborhood™ in suburban Birmingham, Alabama.
She takes a deep breath and leans back in her chair. In her hand is her favorite morning drink (black coffee with no cream). As she takes a sip, she looks south out of her 14th story window. Off in the distance, she can see the Ross Bridge community: the sights of Reynolds Landing and her research. She wonders whether Reynolds Landing will be the future of energy efficient neighborhood construction and a more sustainable method of energy generation and transmission?

Southern Company

Southern Company is one of the largest energy providers in the United States with 46,000 MW of generating capacity and 1,500 billion cubic feet of combined natural gas consumption and throughput volume serving 9 million customers through its subsidiaries. Operations include nearly 200,000 miles of electric transmission and distribution lines and more than 80,000 miles of natural gas pipeline. The company provides clean, safe, reliable and affordable energy through electric operating companies in four states, natural gas distribution companies in seven states, a competitive generation company serving wholesale customers across America and nationally recognized provider of energy solutions, as well as fiber optics and wireless communications.

The makeup of their generating plants has been a subject of scrutiny over the years. Most are fossil fuel plants—meaning they use coal, natural gas, or oil as their main fuel input. Nuclear energy makes up for 15% of the energy and renewables produce roughly 10% of the energy depending on weather. Until recently, coal was the dominant fossil fuel. As business, regulatory and economic conditions have changed, Southern Company continues to transition its fleet and diversify its generation mix. Last year coal generation accounted for less than 30% of the power produced while gas generation made up for nearly half. New nuclear power is also under construction. More recently, they have made investments in solar power across the USA.

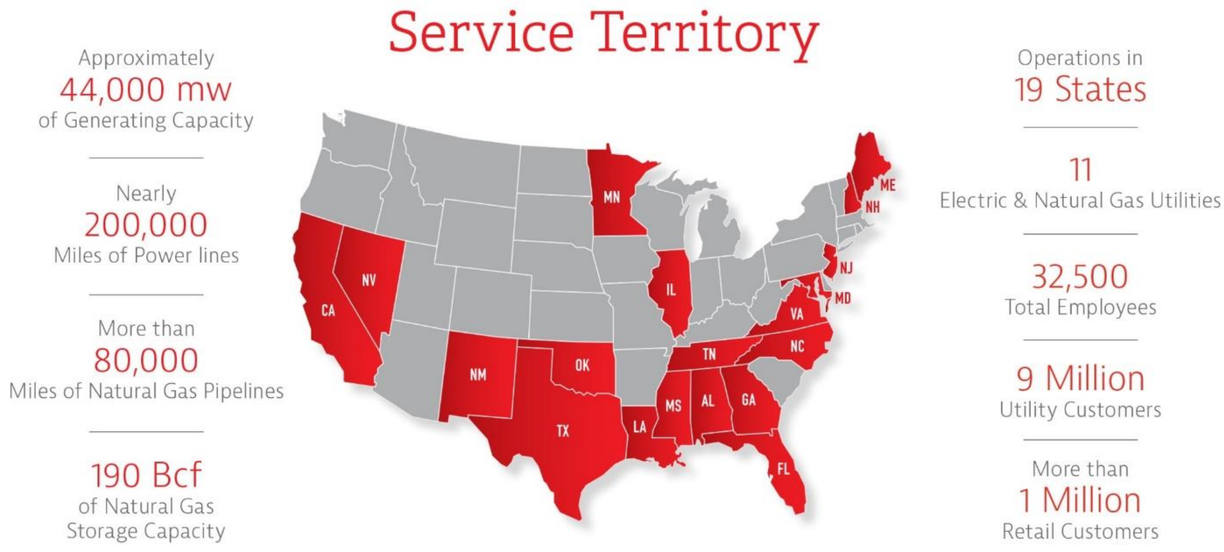


Figure 1 – Southern Company Service Territory

Government Regulation

In the US, electric generation and transmission is heavily regulated by the government at not only the federal level, but also the state and local level. This regulation exists partly because this industry is such that a single provider is often able to provide service at a much lower cost than a combination of smaller companies. This leads to a natural monopoly. Monopolies have the power to restrict output and set prices at levels higher than economically justified. Electricity is considered an essential service for our society and as a natural monopoly, regulation followed. Regulation here means that government agencies oversee the prices utilities charge as well as terms of service to consumers, construction and budget plans, programs for energy efficiency and other services. Government agencies also impose safety and environmental standards on utilities. A good example is the Clean Air Act Amendments of 1990 that limitedthe amount of NOx and SOx emissions into the atmosphere by fossil fuel power plants. The Mercury Air Toxics Standards (MATS) issued in 2011 drove several coal plant retirements as well as retrofitting three existing coal plants to burn natural gas. It is also one of the drivers toward sustainable and renewable energy sources such as distributed energy resources like microgrids.

Microgrids

Getting electricity to your house has two main steps: Creating the electricity (generation) and then getting that electricity from where it was generated to you (transmission and distribution). The physical infrastructure developed over the years across the USA for this is often referred to as "The Grid."

As technology has advanced, some have wondered if generation, transmission, and distribution could be done at a much smaller, local or "micro" level. The Microgrid Institute defines a microgrid as "a small energy system capable of balancing captive supply and demand resources to maintain stable service within a defined boundary." The DOE defines the microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as single controllable entity with respect to the grid…enabling grid modernization and integration of multiple smart grid technologies." Examples include solar panels on the roof of your house that convert heat into electricity and batteries in the garage to store power and lines connecting them to your house to supply power is considered a microgrid. Most microgrids employ multiple sources of power, but today solar is almost always the dominant source in the southeast. It is not the only source, however. Consider what happens with solar power on a cloudy or rainy day. Other supplementary sources include diesel and gas generators, batteries, wind, and water.

A big benefit of a microgrid is the ability to provide resiliency, or uninterrupted power. If power from "The Grid" is interrupted for any reason, a microgrid can take over and continue to provide power. This can be critical for hospitals and other essential services.

Reynolds Landing (https://e-signaturehomes.com/communities/reynolds-landing/)

Since 1969, Southern Company has had a dedicated Research and Development (R&D) organization focusing on developing technologies to provide clean, safe, reliable and affordable energy to customers. In recent years, researchers have been following advances in microgrid technology and use with an interest to learn more. Microgrids represent a potentially disruptive technology to utilities and how they have traditionally operated. Southern Company R&D also has a strong focus on ways to increase energy efficiency. In 2014, they came up with the idea of building a community scale microgrid that would have a connection to a full neighborhood of homes with connected/smart appliances and features. Exhibit 2 shows an overview of the project. It took a full 2 years to gather the stakeholders, obtain funding and gain regulatory approval. In partnership with Signature Homes and others, they selected Reynolds Landing in Ross Bridge, AL as the site for the 62 smart homes along with a community-scale microgrid.

The microgrid was designed to produce 600,000 kWatts annually (Exhibit 3). It is comprised of a non-rotating solar panel array, lithium ion battery storage and a natural gas back-up generator. The microgrid site is 13.9 acres and is located about 1 mile away from Reynolds Landing opposite an existing apartment complex. A dedicated line to the neighborhood from the microgrid is in place, but the facility can also send its power to "The Grid."

The homes range in price from around $340,000 to $450,000. Homes have a square footage of around 1,900 sq ft to 3,000 sq ft depending on the model. Between their grand opening on June 24, 2017 and the year's end, Signature Homes had sold all 62 homes sites – this has been one of their top-selling communities. The first homeowner moved in before Thanksgiving and there are 22 families currently settling into their new homes.

All the homes come standard with energy efficient features and smart appliances. The refrigerator, oven, dishwasher, microwave and washer/dryer are connected appliances included with each home.

Table 1 gives an example of some of the energy efficient features.

Reynolds Landing	2017 Standards
2x6 walls with R-24 blown in blanket insulation	2x4 walls with R-13 blow in blanket insulation
Radiant barrier roof decking to reduce hot attic temperatures	Standard roof decking
R-49 blown attic insulation	R-30 blown attic insulation
Triple Pane Low E windows	Double Pane Low E windows

Table 1 – Energy Efficiency Comparison

The window shades, lights, and thermostat can all be controlled remotely with an iPad or other connected devices. The doors have smart locks with keyless entry and the house alarm is voice activated. Figure 2 give an example of a dashboard homeowners can pull up showing detailed energy usage. In return for many of these standard upgrades, each homeowner has to agree to data collection for 2 years. They also have to respond to monthly surveys and questionnaires.

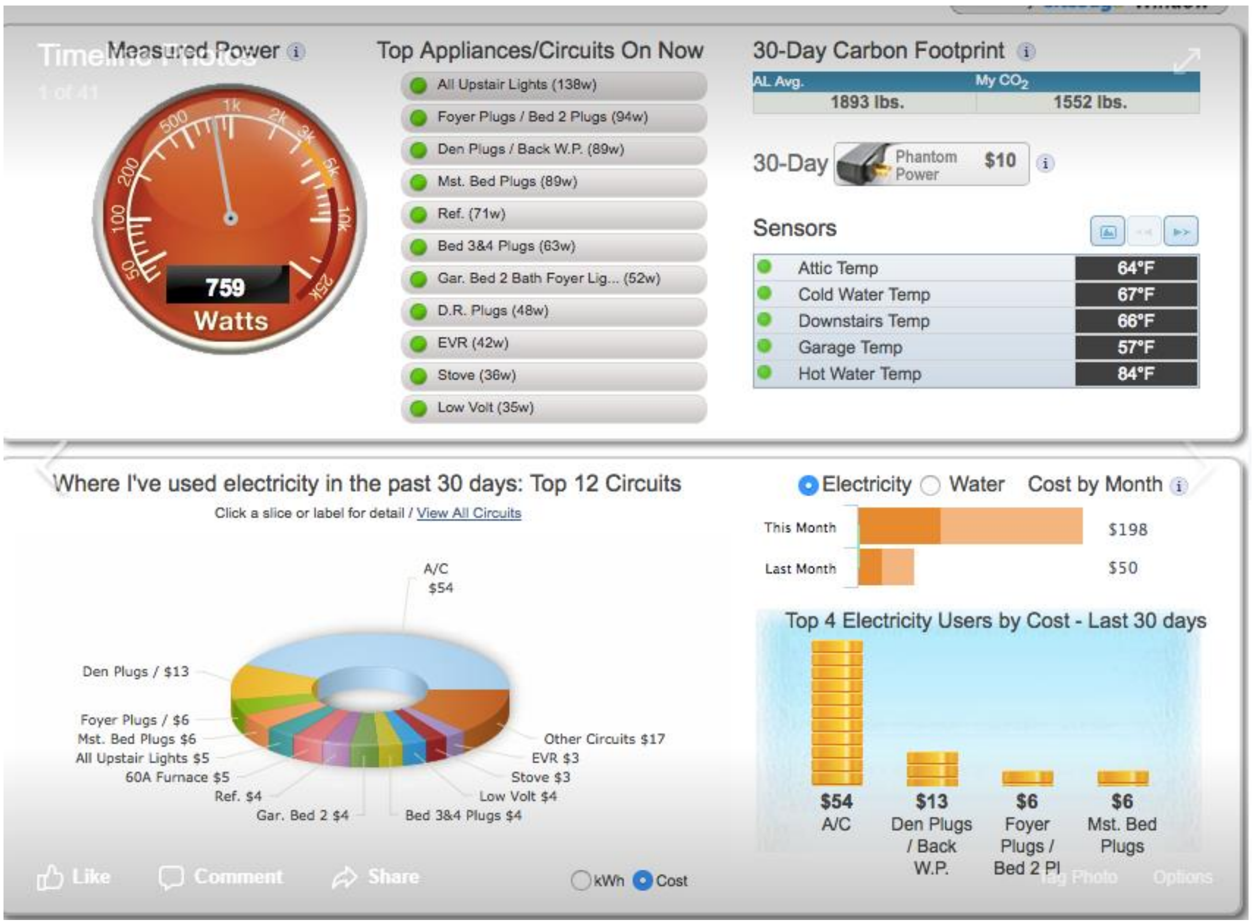


Figure 2 – Sample Homeowner Dashboard

R&D at Reynolds Landing

With 62 different families coming early in 2018, West knew she would have a fertile test environment. She has two main research focuses here. The first centers around learning from a community-scale microgrid. How to connect distributed energy sources (like a microgrid) to a larger grid or how to operate them as "islands". What kind of benefits may be provided to the grid such as load and frequency control or voltage regulation? How can adverse impacts such as storm outages be mitigated?

The second is how people use energy in their homes. The depth of data that will be collected from these homes is unprecedented. Data will be collected every minute from a variety of sensors in most appliances as well as temperature gauges throughout the home, the HVAC system and the water heater. Exhibit 5 shows the data collection and transmission point on the wall in the garage. There have been single houses looked at before, but never a full neighborhood and never one with all the features and technology here.

Among some of the bigger questions West had were:

1. What kind of new business models can come out of this? Will consumers engage demand response signals and should the residential rate structures be overhauled? What issues/concerns should one anticipate?

2. What are the main issues and opportunities that will come with owning and operating a community scale microgrid? Do any commercial applications exist?

3. What are some must-test scenarios for the next 2 years?

4. Consider that over 45% of Southern Companies customers make less than $40,000 a year. What smart technologies seem the most promising to this segment of the customer base?

5. What should R&D include in the next phase of research (like bi-directional EV charging)?

<u>Exhibit 1 Tracy West 2017 Congressional Testimony</u>

Buildings-to-Grid Oversight Hearing for U.S. Senate Committee on Energy and Natural Resources

Written Testimony of Tracy West, Director, End Use, Power Delivery and Fleet R&D
Southern Company, 600 North 18th Street, Birmingham, AL 35203
(205) 757-3123; tlhawkin@southernco.com

Chairman Murkowski, Ranking Member Cantwell and distinguished members of the Senate Committee on Energy and Natural Resources, my name is Tracy West, and I am a director in research and development (R&D) at Southern Company, overseeing the power delivery and end-use research programs. I would like to thank the Committee for the opportunity to speak with you today as we discuss buildings-to-grid integration and how these technologies can bolster the relationship and interaction between customers and their utility.

As you know, the U.S. energy industry is rapidly changing. Drivers include:

- Evolving customer expectations and choices
- New technologies
- Slow economic growth and reduced demand
- Reduced cost and growth of renewables, storage and other distributed infrastructure
- Changes in regulatory policy
- Stakeholder pressure
- New market competitors

Southern Company recognizes that accelerating technology development is more important than ever in this challenging environment. Since the 1960s, Southern Company has managed over $2.3 billion in R&D investment and remains the industry leader in the U.S. in research, development and deployment of innovative energy technologies. Over the past decade, Southern Company's leveraged R&D investment of $436 million has returned benefits exceeding $3.4 billion.

At Southern Company, we put our 9 million customers at the center of everything we do. From operations and maintenance to R&D, America's premier energy company provides 46,000 megawatts of generating capacity, 200,000 miles of power lines and 1,500 million cubic feet of combined natural gas consumption and throughput volume. And through a joint venture, Southern Company and Kinder Morgan share ownership of the 7,000-mile Southern Natural Gas pipeline system and are exploring future infrastructure development opportunities. Southern Company provides clean, safe, reliable and affordable energy through electric operating companies in four states, natural gas distribution companies in seven states, a competitive generation company serving wholesale customers across America and a nationally recognized provider of customized energy solutions.

Through an industry-leading commitment to innovation, Southern Company and its subsidiaries are inventing America's energy future by developing the full portfolio of energy resources, modernizing the grid for resiliency and security, and creating new products and services to benefit our customers.

Today I'm here to share with you Southern Company's buildings-to-grid efforts, and how we're building the future of energy through our diverse, innovative research, development and demonstration portfolio.

Buildings-to-grid communication and integration technologies could revolutionize the way we make, move and sell energy. So, what exactly does it mean? Buildings-to-grid communication allows the utility to actively engage with end-use assets scattered across a geographic area, enabling utilities to meet customer demand while employing fewer peaking generation assets or cycling our assets and increasing the resiliency and flexibility of the grid.

I'd like to discuss a handful of our R&D projects currently underway in the buildings-to-grid space. I'm going to start with and spend the most time describing our newest buildings-to-grid initiative – the Smart Neighborhood projects.

Back in 2014, we were having conversations about what the utility industry might look like in the future. These conversations were bracketed by disparate views. On one hand, people thought the industry would remain the same with a focus on centralized power as the low-cost provider. Others recognized rapidly advancing technology and changing economics could drive the industry toward microgrids and distributed energy resources (DER).

As a result, the Smart Neighborhood concept was born.

Two Smart Neighborhoods were proposed to proactively simulate two scenarios for residential customers in a world where DER and microgrids become key to powering the country. The first focuses on a community-scale microgrid, where resources are shared and managed at the neighborhood level to provide cost savings through economies of scale. The second focuses on customer-owned, behind-the-meter DERs that are managed on behalf of the homeowner to reduce energy costs, improve comfort and supply energy to the grid as a resource. By implementing these projects now, we prepare ourselves to remain the energy experts and adapt to maintain our competitive advantage in the utility space. These projects consist of three main pillars:

1. **High-Performance Homes:** Building codes and appliance standards continue to drive energy efficiency changes throughout the country. In anticipation for these changes, these projects include technologies and building practices that are much higher than the minimum of today. These high-efficiency construction techniques will model the energy performance of homes that will be the norm 20 years from now.
2. **Distributed Energy Resources:** DER assets on both residential and community-scales are a key component to these two projects. As DER costs continue to decrease, these projects allow us to study the impacts of solar panels, natural gas generators and batteries at the edge of our grid, while developing new strategies to integrate them seamlessly into real-time grid operations.

3. **Buildings-to-Grid Communication:** The third pillar is a way to integrate customer resources onto the grid by using their energy flexibility and thermal energy storage (in heat pump water heaters). This integration capability is enabled by the proliferation of low-cost and robust communications, as well as the widespread adoption of the Internet of Things. Shifting toward a utility that can actively engage with assets scattered across a large geographic area will enable us to meet customer demand while employing fewer peaking generation assets and increasing the flexibility and resiliency of the grid.

To continue providing value-driven solutions for our customers, we must understand the challenges and opportunities currently unfolding in the industry and how it impacts them. With that, these Smart Neighborhood projects are the first large-scale projects of their kind, integrating connected technologies with DER assets to explore how these independently-tested technologies can benefit both customers and the grid.

Alabama Power's Smart Neighborhood in Birmingham, Alabama, consists of 62 single-family dwellings and a community-scale microgrid located nearby. This project aims to:

- Understand high-performance homes and customer experiences
- Determine which programs and services can provide new energy solutions for customers
- Evaluate community-scale microgrids
- Explore buildings-to-grid opportunities for load shaping within a community-scale microgrid
- Build relationships with homeowners to obtain real-world feedback on new home technologies and future utility business cases

Georgia Power's Smart Neighborhood in Atlanta, Georgia, is made up of 46 townhomes that make up the first phase in a larger community buildout of an additional 224 townhomes and commercial facilities over the next several years. Each townhome will be equipped with rooftop solar, battery energy storage, connected heat pump water heaters and thermostats. The goal of this project is to:

- Understand the impacts of behind-the-meter rooftop solar and battery storage
- Understand the impacts of customers supplying energy back onto the grid
- See how highly-efficient townhomes perform
- Develop new methods to integrate rooftop solar, battery storage and controllable devices to benefit the homeowner and the grid
- Investigate how heat pump water heaters can be used for thermal energy storage
- Investigate future rate design models to incorporate new technologies and customer behaviors

Before concluding this discussion about our Smart Neighborhood efforts, I stress that these projects would not be possible without our partnerships with key stakeholders, research organizations and influencers across the industry. Through funding from the Department of Energy (DOE), Oak Ridge National Laboratory (ORNL) has been developing the control systems, VOLTTRON and CSEISMIC, for the Alabama Smart Neighborhood project. VOLTTRON is the home energy management system that will communicate with the water heater and HVAC systems, and CSEISMIC is the microgrid controller that will control the generation assets and communicate with VOLTTRON. The value of the Alabama project has been strengthened by working across unit lines at DOE. The collaboration between the Buildings Technology Office and the Office of Electricity has been key to enabling the success of this multidisciplinary project.

Successes and obstacles from these projects will be applicable across the country, as the Southeast sets the stage for future Smart Neighborhoods. With these projects, we will be able to envision tomorrow's homes, today.

While these Smart Neighborhood projects are gaining national interest, Southern Company is leading additional buildings-to-grid initiatives that include:

- **Sustainable and Holistic Integration of Energy Storage and Solar PV (SHINES):** This Electric Power Research Institute-led, DOE-funded project is integrating solar PV systems, advanced solar forecasting techniques, load management and energy storage with the power delivery network at three test sites across the country. Southern Company R&D and Gulf Power are performing a residential demonstration at two side-by-side Pensacola homes to better understand the capabilities of residential appliances to respond to grid and solar PV signals.
- **ORNL Grid Modernization Lab Call:** *Unified Control of Connected Loads to Provide Grid Services, Novel Energy Management and Improved Energy Efficiency.* This project looks at a way to upgrade the controls within small commercial convenience stores to use the flexibility and thermal storage capability of refrigeration for non-perishable items (soft drinks, etc.). Southern Company is working with ORNL and Emerson Climate Controls to develop, test and implement this control strategy within our footprint.
- **Integration of Responsive Residential Loads into Distribution Management Systems (IDMS):** In a partnership between ORNL, EPRI and other utilities across the southeast, Southern Company is investigating how a fully open standard-based technology framework can be integrated into our distribution management system. This project will allow us to understand different value streams that connected buildings can offer to the grid and the appropriate internal function of control and hierarchy of priorities to gain the most beneficial implementation.
- **Water Heaters as Thermal Energy Storage:** We are deploying a small number of grid-interactive water heaters across our service territory to integrate them with our daily grid operations. The work will include open protocols for integration and may be expanded to proprietary algorithms and information exchanges to extract the most value from the water heaters as possible.

At the forefront of technology development for making, moving and selling electricity, Southern Company actively collaborates with other utilities, universities, U.S. government, national labs and vendors. Our leadership and vision helps invent real solutions for America's energy future.

We are focused on meeting customers' energy needs today and building the future of energy as we anticipate tomorrow. With these buildings-to-grid projects, Southern Company will remain energy experts and adapt to maintain our competitive advantage in the utility space. As these programs develop and the energy landscape shifts, we intend to lead the change to serve our customers with clean, safe, reliable and affordable energy.

Thank you for the opportunity to testify today – I am looking forward to answering any questions you may have.

Exhibit 2 – Reynolds Landing Project Highlights/Overview

Alabama Power

SMART NEIGHBORHOOD™

Objective

Design and build a first of a kind living laboratory to prepare APC for future grid needs and customer expectations

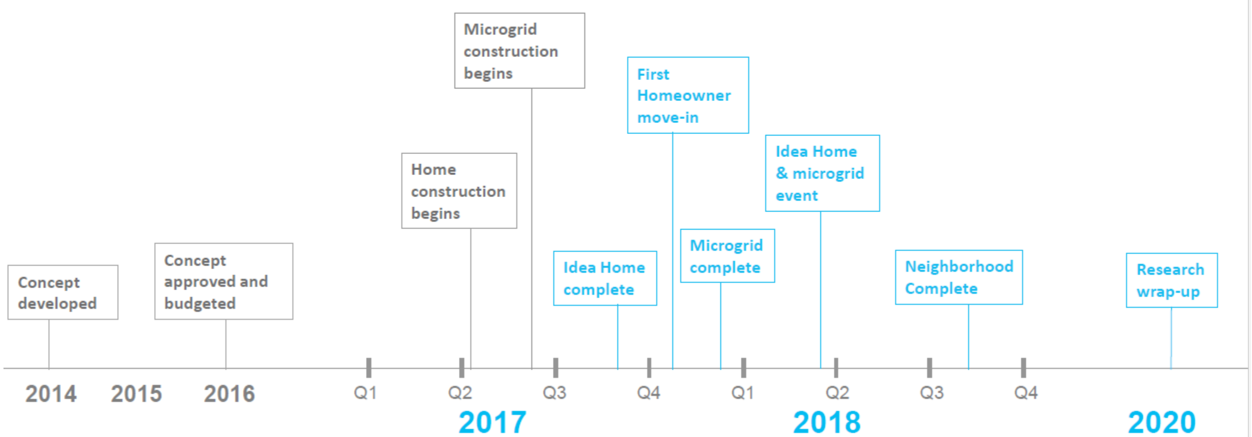
Scope

Demonstrate **distributed energy resources (DER)** use cases optimizing cost, reliability, and environmental impact with a **community-scale microgrid**

Planned neighborhood of 62 homes with **energy efficient construction** and **connected home devices** providing an improved customer experience

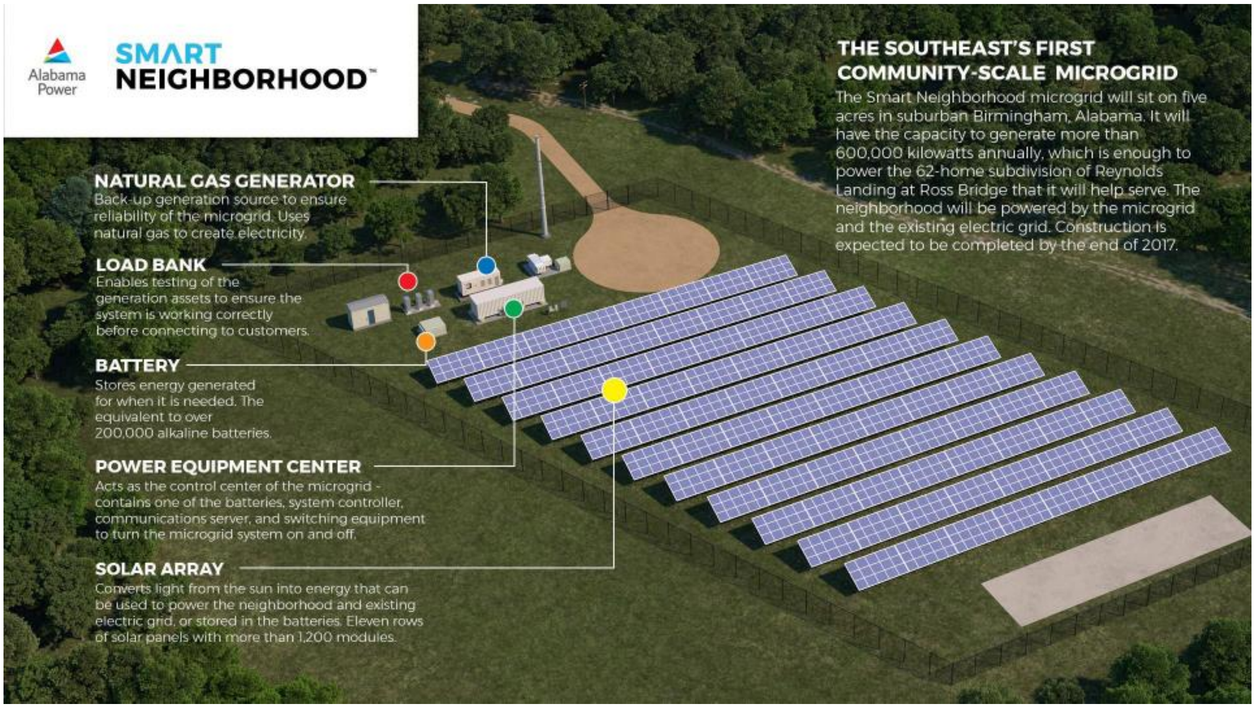
Demonstrate **building-to-grid integration** with real time utility to customer interaction

PROJECT TIMELINE



PROJECT OVERVIEW

Exhibit 3– Reynolds Landing Community Microgrid



Above: Schematic of Microgrid

Above: Actual Solar Array and Prof

Above: Actual Load Bank and Profs

Exhibit 4 – Reynolds Landing Smart Home Technologies/Features

HEATING & COOLING

Carrier®
turn to the experts

Incredibly energy efficient technology.

Carrier® Infinity® Heat Pump
with Greenspeed™ Intelligence
plus Infinity® Remote Access Touch Control Thermostat

- **Adapts** to the needs of your home
- Operates longer at steadier, lower capacities, ensuring **incredible energy efficiency and quiet operation**
- **Touch control thermostat** can manage temperatures, humidity, ventilation, airflow, indoor air quality and up to eight zones
- **Wi-Fi enabled** remote access

Photos courtesy of Carrier

WATER HEATING

Rheem

The most efficient way to heat water.

Rheem Professional *Prestige*® Series
Hybrid Electric Water Heater

- 50, 65, 80 gallon capacities
- LCD display with built in water sensor alert with **audible alarm**
- EcoNet WiFi- connected technology and mobile app **gives users control** over water system
- Customizable temperature control with **energy savings mode** and **vacation mode**

Photo courtesy of Rheem MFG

THERMAL ENVELOPE

Building better.

- Advanced air sealing
- 2x6 Zip walls with R-24 blown in blanket insulation
- Radiant barrier roof decking to reduce hot attic temperatures
- R-49 blown attic insulation
- Triple Pane Low E windows

What does all this mean to homeowners?

Less heat gets into your house in the summer, and cold in the winter. This helps you stay **more comfortable** and your home **more efficient** all year round.

SMART APPLIANCES

SAMSUNG

Efficient, Effective, Effortless

- 4-door Flex Refrigerator with **Family Hub** in the door with Internet connectivity
- Slide-in **Induction** Range for the most efficient and safest cooking technology available
- Over-range microwave with **PowerGrill** to toast and broil
- Top control dishwasher with **WaterWall** cleaning technology
- **AddWash** Front-load Washer with Steam
- Electric Dryer with **FlexDry** Technology

Photos courtesy of Samsung

HOME CONTROL, SECURITY & ENTERTAINMENT

vivint. SmartHome

The brains behind your smart home.

- **Voice-activated** security system
- Smart locks allow for **keyless entry**
- **Lighting control** to manage lights throughout the house
- Smartphone **linked cameras** to monitor your home from afar
- Smart **garage door control**
- **Google Mesh**
- **Amazon Dot** integration

Exhibit 5 – Data Collection Hub at a Smart Home (Wall of garage)